


2013

# METR 200: Weather and Climate—A Peer Review of Teaching Project Benchmark Portfolio

Matthew S. Van Den Broeke

*University of Nebraska-Lincoln*, [mvandenbroeke2@unl.edu](mailto:mvandenbroeke2@unl.edu)

Follow this and additional works at: <http://digitalcommons.unl.edu/prtunl>

 Part of the [Atmospheric Sciences Commons](#), [Climate Commons](#), [Higher Education Commons](#), [Higher Education and Teaching Commons](#), and the [Meteorology Commons](#)

---

Van Den Broeke, Matthew S., "METR 200: Weather and Climate—A Peer Review of Teaching Project Benchmark Portfolio" (2013).  
*UNL Faculty Course Portfolios*. 42.  
<http://digitalcommons.unl.edu/prtunl/42>

This Portfolio is brought to you for free and open access by the Peer Review of Teaching Project at DigitalCommons@University of Nebraska - Lincoln. It has been accepted for inclusion in UNL Faculty Course Portfolios by an authorized administrator of DigitalCommons@University of Nebraska - Lincoln.

# Peer Review of Teaching Benchmark Portfolio (2013)

## METR 200 (Weather and Climate)



**Matthew S. Van Den Broeke**

**Assistant Professor**

**Department of Earth and Atmospheric Sciences**

**University of Nebraska-Lincoln**

**306 Bessey Hall, Lincoln, NE 68588**

**Tel: 402-472-2418**

**Email: [mvandenbroeke2@unl.edu](mailto:mvandenbroeke2@unl.edu)**

# Table of Contents

Objectives of this Portfolio .....	3
Description of METR 200 .....	3 – 6
Overview of METR 200 and Students .....	3
Relationship of METR 200 to Department & College Curriculum .....	4
Goals for Student Learning .....	4 – 5
Specific Challenges with METR 200 .....	5 – 6
Course Objectives for METR 200 .....	6
Teaching Methods, Course Materials, and Course Activities .....	6 – 10
Teaching Methods during Contact Time with Students .....	6 – 8
Course Activities Outside of Class .....	8 – 9
Course Materials .....	9 – 10
METR 200 Design and the Broader Curriculum .....	10 – 11
Analysis of Attainment of the Course Objectives .....	11 – 27
Overview of Analysis Methodology .....	11 – 13
Objective 1 .....	13 – 18
Objective 2 .....	19 – 21
Objective 3 .....	21 – 23
Objective 4 .....	23 – 25
Identification of Particularly At-risk Students .....	25 – 27
Summary and Planned Changes to METR 200 .....	27 – 28
Assessment of the Portfolio Process .....	29
Appendices .....	30 – 55

# I. Objectives of this Portfolio

This benchmark portfolio is meant to be an assessment of how well the objectives of METR 200 (Weather and Climate) are being attained by students in several classifications of academic major. Students from a wide range of backgrounds enroll in this course as a general science elective, and for many, it will be the only science course taken in college. Thus, it is important that course material be sufficiently accessible for all students, while providing meaningful information which will be applicable by students of all backgrounds once they leave the course. In this portfolio, an analysis will be presented showing how well each of the four course objectives are being attained by students in each classification of academic major. Arising from this analysis, changes will be proposed for future sections of METR 200 which should allow the course to more fully reach its objectives among a broader sample of enrolled students.

## II. Description of METR 200

### A. Overview of METR 200 and Students

Weather and Climate (METR 200) is an introductory-level course in which students learn the fundamentals of atmospheric science. They gain a foundation of concepts which can be applied to diagnose why the atmosphere is producing a given phenomenon. Students begin the application process by looking at recent and current weather events in class, in homework and exam problems, and while completing a project.

METR 200 students, undergraduates in all four years of study, come from a wide range of backgrounds. While some are meteorology-climatology majors, most are non-majors and many are non-science majors. Non-meteorology majors are either interested in the topic, or more commonly, are taking the class to obtain science credit (METR 200 is an ACE-4 course). Many students take the course as part of the natural science endorsement of the Teacher Education Program. One significant challenge is balancing the needs of students from diverse backgrounds. While some students love meteorology, others are neutral about science or even terrified to be taking a science course. One group of students already has a fundamental background in some of the course material, while other students struggle to grasp concepts such as pressure and temperature.

## **B. Relationship of METR 200 to Department & College Curriculum**

This course fits into my department's curriculum as the foundational meteorology course which majors are required to take. As such, students need to leave METR 200 with a good basic understanding of a wide range of atmospheric processes and phenomena. My goal is for students to be able to take what they learn in this class and apply it throughout their learning experience as meteorology students, and to routinely apply what they have learned to real-time atmospheric data. This may also be the overarching goal of the meteorology-climatology program—for students to apply their textbook knowledge to real-world problems. In this way, I try to attain a first step toward the overall goal of my department in asking students to explain and make decisions about ongoing or past weather events. At the same time, these exercises need to be designed to engage non-majors—ideally, they will also be able to take what they learn in METR 200 and apply it to their daily observations of the atmosphere after they leave the course. Ultimately, then, course goals are similar for major and non-major students.

It should be noted that course goals are similar to the ACE-4 goals of inquiry (formulating questions for scientific investigation), analysis (processing data), interpretation (making well-supported statements resulting from data analysis), and inference (applying interpretation and thinking through the implications of what has been learned). In this way, the process of assessing the course's program-related goals and ACE-4 related goals should be very similar.

## **C. Goals for Student Learning**

It is important to consider what students should be able to do after leaving the course—what should they retain and be able to apply later? Majors should retain the foundational concepts governing how the atmosphere works, and the ability to use weather data to draw appropriate inferences. Non-majors may not need to use the fundamental material again, but it would be useful for these students to be able to look at weather data in the future, be able to analyze and interpret it, and have a basic idea of what it means for their situation (e.g. is there a significant tornado threat today? Will tomorrow likely be warmer than today?). For both groups of students, this implies a need to think critically and apply their knowledge to situations they have never seen before. Course exercises, exams, and a project give students practice at this higher-level application. Students should also gain an ability to think critically about scientific content, and be able to analyze the logic presented to identify obviously-false assumptions or information. In an era with increased scientific information availability, of highly-varying quality, students should be able to make informed choices about what constitutes a good source of scientific information. Students should leave METR 200 appreciating the complexity of the weather and climate system, not afraid to think critically

about scientific concepts, with heightened curiosity about the natural world, and with the ability to recognize misleading information.

Students should learn something about themselves and their role in society from their experience in METR 200. They should learn science is surmountable—given a curiosity about the natural world, they can take initiative and learn something meaningful about it. They should see their own capacity to think critically, and would ideally be able to apply a new level of criticality to their other coursework and lives in general. For many students this will be their only science course at a college level, so they should also understand their need to be informed citizens, contributing positively to society by maintaining high standards for the level of scientific knowledge present in the culture.

The goals stated above are necessary for students to attain because the society as a whole, and the younger generation in particular, are losing the practical, scientific knowledge which was taken for granted in prior generations. For instance, each semester some of my METR 200 students do not know that the sun rises in the east, and many believe the northern hemisphere summer is caused by Earth being closest to the Sun during this time. Without a fundamental understanding of such concepts, it is easy to accept false information which purports scientific accuracy. Misconceptions about science greatly affect policies constructed to deal with societal issues, and misguided policies can do more harm than good. The current generation of students will be tomorrow's leaders, so the more sound science they have for decision-making and policy-making, the better. These goals are also appropriate for the students, because they are often immersed in a technological world and only rarely take the time to observe and think carefully about the natural world around them. Though it is impossible for one course to remedy this problem, hopefully if well-structured it can get most students to think about these issues on a deeper level.

#### **D. Specific Challenges with METR 200**

There are several significant issues with teaching a large lecture-based science course including a large number of non-science majors. Among these are keeping students engaged and motivated in a large lecture section, which has proven challenging in prior experiences teaching this course. In the past, I have given scattered pop quizzes, but haven't felt this method provides the right type of motivation. I would like classes to become more interactive, and would like to get students involved in more frequent discussions. Also, with the combination of majors and non-majors, I would like to teach the course such that both groups of students leave with meaningful information and skills. A final concern prompting me to create this portfolio is fair and succinct assessment of course goals. I need to critically assess how well the course is

attaining its ACE-4 goals and the broader goal of having students come away with the ability to think critically about scientific data and information. I will also be teaching three courses during the Spring 2013 semester alongside research, and two of the courses are new (METR 200 is not). Past grading has taken significant time, particularly application-based exam questions. Thus, I would like to give thought to how I might assess progress toward course objectives without using unnecessary time.

#### **E. Course Objectives for METR 200**

Given the discussions above, the following objectives have been developed for METR 200. These statements appeared on the course syllabus (see [Appendix A](#)).

**Objective 1:** Develop a good understanding of basic atmospheric properties and processes.

**Objective 2:** Develop the ability to interpret meteorological data, draw appropriate inferences from it, and apply meteorological concepts to new weather situations.

**Objective 3:** Think and write critically and scientifically about weather events, and be able to assess the scientific validity of content.

**Objective 4:** Appreciate the complexity of daily weather and the climate system, and apply course material to your observations of the natural world.

### **III. Teaching Methods, Course Materials, and Course Activities**

#### **A. Teaching Methods during Contact Time with Students**

Several teaching methods were used during contact time with students, including standard PowerPoint-based lecture, weather discussions to illustrate course concepts and connect students to real-time use of weather data, and review of course material via sessions in which students ask questions about homework assignments and upcoming exams.

The core of each course meeting was an interactive PowerPoint lecture. Students were expected to come to class having read the appropriate section in the book, so lectures served to reinforce and expand upon this material. Each lecture was designed to present the key

concepts from one or two primary topic areas, and contained as many applications as practical. During the early part of the semester when students were still learning foundational scientific principles, many of these applications were to everyday processes students are likely to have observed (e.g. filling a bike tire or a balloon; a spinning ice skater). Once more specific weather-related concepts were introduced, many applications were either to weather phenomena students are likely to have observed, or to ongoing weather events. These real-time events were taken from Nebraska or the Great Plains when possible. Using real examples, especially ongoing examples, seems to capture student attention more effectively. Allowing students to make a clear connection between material learned in class and phenomena readily observed in the world around them helps motivate students and keep them invested in the course.

Once students have been taught basic weather map reading skills, the majority of following classes started with a weather discussion. These discussions pulled from and added to skills taught in class, and further reinforced the use of these skills to interpret ongoing weather. Weather discussions most often focused on North America, with further discussion of Nebraska weather when appropriate, but were occasionally expanded to include weather in other regions. For example, tropical cyclones were shown in the South Pacific and South Indian basins. The primary rationale for weather discussions was to immerse students in application of course concepts to real, ongoing weather events. After leaving METR 200, students should then have more experience to draw from and are more likely to apply course concepts to the real world.

Some course meetings ended with homework help sessions or exam review sessions. During this time, students asked questions about their homework problems, and reviewed course concepts in preparation for exams. I also questioned students to get them thinking about key concepts. This time served to reinforce principles being learned, and provided an additional way for students to ask specific questions about things they had a hard time understanding.

These methods were helpful for me to assess student learning. PowerPoint lectures were somewhat interactive, and students were able to ask and answer questions which helped me judge their level of understanding. Weather discussions functioned similarly. When I have used weather discussions in the past, I found students in large lecture sections are especially willing to open up and ask questions, perhaps because the material being discussed is perceived as more directly applicable, and it often affects the students directly (in the case of Nebraska weather). Homework help and exam review sessions were particularly helpful for me to assess student learning, as students asked questions during these time specifically about what they did not understand. From these questions, I was able to judge whether students grasped the most important concepts. I often followed with questions to help focus their thought, and the



responses helped me judge whether their understanding is superficial (fact-based) or deep (they can meaningfully apply it).

Students enrolled in METR 200 also participated in a weekly lab section taught by a lab assistant. During lab meetings, students heard an additional short lecture related to and often extending course material. Then, students went through a series of hands-on activities designed to give them experience applying course concepts to real weather situations. Lab exercises were mostly pre-written, but also contained supplementary sections designed to be more connected with ongoing weather. I also wrote an additional lab exercise which allowed students to learn about the application of new radar technology. I often discussed student progress with the lab instructors, and sought to understand which areas are the most difficult for students. A short discussion was added to lecture meetings for especially difficult topics.

## **B. Course Activities Outside of Class**

Students performed a number of structured tasks outside of class. These included several homework assignments with different goals. The first four homework assignments were assigned as appropriate course material was discussed, and were due once we finished discussing the material and prior to the following exam. These homework assignments served two purposes: 1) Reinforce factual knowledge gained in class, and 2) Allow application of this material. In an introductory-level meteorology class, particularly with a majority of non-majors, it is important to ensure students are reviewing the key foundational material. Thus, a few questions on each assignment required students to draw on factual knowledge learned in class. An additional set of questions asked students to do something with this knowledge—they sometimes had to go find a current weather map and say something about it, or, given some weather data, they had to diagnose the situation and make a forecast or say something about the societal implications. Application questions became more common as the semester progressed, since students learned most of the foundational material early in the semester. Several questions on homework assignments also had students complete online learning modules designed by the University Corporation for Atmospheric Research (UCAR). Many of these modules take students through a highly-structured learning experience relevant to course material, and teach students material beyond what they learn in class. Student performance on these first four homework assignments was assessed using a traditional grading scheme.

The last two homework assignments of the semester were assigned near the beginning of the semester and due by the final exam. They required students to apply course knowledge to ongoing weather (Homework 5), and asked students to learn additional material in an area of personal interest (Homework 6). In Homework 5, students found a series of meteorological

features in weather data from the semester (examples prior to the current semester were not given full credit), and said something about weather in the vicinity of the feature of interest. Examples of possible features for students to find included a cold front, upper-level trough, or coupled jetstreak pattern. Features were fairly common and not extremely challenging to find if students were routinely looking at weather data (which was encouraged). The purpose of this assignment was to further encourage students to be looking at weather data on a regular basis, and to have them think about how weather features affect local weather. Homework 6 had students find either a scientific journal article about a topic of personal interest (I supplied some possible articles), or a newspaper article (print or online) about some aspect of weather and climate. If students chose a journal article, they were required to write a several-page summary and critique of the article. This exercise immersed students in good scientific writing and logical thought, and had students think about what can be learned from scientific research, about research design, and about what they liked and did not like about the article they choose. For students selecting a news article, they had to write a several-page discussion of the science in the article, addressing scientifically-valid and scientifically-lacking points. This exercise was designed to make students think critically about scientific content they are presented by the media, and to identify points which need improvement. Assessment of student performance was accomplished on Homework 5 by determining whether students correctly identified the feature of interest and its local weather effects. On Homework 6, students were assessed on the quality of their scientific analysis, and on the quality of their writing.

Students were also strongly encouraged to come to office hours outside of class for additional help, though this could not be mandated. When students came to office hours, their questions were answered via interactive exercises, including drawing and the use of real-time weather data when appropriate. They were also asked additional questions to ensure they were developing a deeper level of understanding and the ability to meaningfully apply concepts they were having difficulty understanding.

### **C. Course Materials**

METR 200 used the textbook *Weather Studies: Introduction to Atmospheric Science*, 5<sup>th</sup> edition, published by the American Meteorological Society (AMS). This book was used because it is friendlier for an online course setting. Since METR 200 may be transitioned to a course with online sections, it was mandated that we try this textbook for one academic year (2012 – 2013), after which time it was to be evaluated for further use. I feel the book is poorly-organized and relatively poorly-written compared to other books I have used and examined for introductory weather and climate courses, so it would not be my choice of textbook. I was able to develop reading assignments, many taken from several locations within the textbook, which followed

what I believe to be a better organization of the material. Thus, the textbook should have been helpful to students if they followed the reading assignments.

The lab manual we used is *Investigations Manual: Weather Studies*, also published by the AMS, and also was used because it is highly compatible with an online course format. The labs are too simple and require too much reading of material which is covered in class, so I am also not happy with this lab manual. To provide a better lab experience, students were given supplemental questions in which they applied lab concepts to a real, or possibly ongoing, weather situation. One lab was written from scratch and taught students how to interpret polarimetric weather radar data. These additions somewhat lengthened the labs, but should have provided students with a more concrete connection between the science and things they can observe in day-to-day weather.

For each PowerPoint lecture, a lecture outline was prepared and made available to students through Blackboard. It contained blanks and places for students to write about key concepts as they followed along with the lecture. Students had a choice about whether to use the lecture outlines—some students liked this additional level of organization, while other students preferred to take their own notes. Lecture outlines contained all the key concepts from lecture, and provided a compact knowledge base which students could use while studying for exams or while working on homework assignments.

UCAR's interactive teaching modules were also used on homework assignments, and some were given as supplemental but non-required activities for those students who wanted to learn more about a particular topic. Extra credit was given for this additional activity. On homework assignments, students often seemed to appreciate the level of interactivity provided by these modules, and the end-of-module quizzes provided a simple and quick way to assess student comprehension. Additional modules allowed students to further explore areas of personal interest in a controlled and well-developed environment with little instructor supervision.

## IV. METR 200 Design and the Broader Curriculum

My choice of methods, materials, and activities was not strongly influenced by students' prior experience. My course assumed no prior knowledge of weather and climate, and little prior scientific knowledge. It was meant to be relatively self-contained, with only minimal prior scientific knowledge and relatively simple mathematical knowledge. This course may, for many students, be their only exposure to science in college. Thus, it was designed to give students a

relatively immersive experience in which they learned a body of scientific knowledge, saw how to meaningfully apply that knowledge in daily life, and developed some basic skills to identify scientific validity of content related to weather and climate.

My course must prepare meteorology majors (a minority of the class) for their future coursework in the major. Since this is the initial course in the meteorology-climatology major, its primary purpose is to give students a foundational knowledge base on which they can build, and as such, methods may not be as important so long as they accomplish this goal. Programming is a key component in many future courses, but this cannot be required of the majority of METR 200 students and would not be especially helpful for the conceptual type of learning emphasized. Students get a good foundational base in weather map analysis and applications of weather data, which is a key skill further developed in future meteorology-climatology courses.

By their experience in METR 200, students should be better-prepared for future courses and for their endeavors beyond graduation. Students gain an ability to interpret and apply data, which is the key endeavor in almost any discipline or job. Types of data change between fields, but ultimately, students will be required to think in similar ways about their observations. Many of my students were future teachers or scientists and engineers, and this coursework should significantly benefit them. For students without such interests, the ability to think critically about data is still useful. This is especially true in the realm of media reports about scientific research—it is vital for non-scientists to be sufficiently informed so they can distinguish good from bad science, and can make informed decisions using scientific knowledge. Weather and climate has an additional application for non-scientists, as anyone can use the concepts learned in METR 200 to diagnose their weather situation and have a good idea of what weather to expect for the next several days using current data. A few students each semester maintain a keen interest in weather, and many use meteorological data well after the semester ends.

## V. Analysis of Attainment of the Course Objectives

### A. Overview of Analysis Methodology

Four learning objectives were stated in the course syllabus (see [Appendix A](#)). In the remainder of the portfolio, I will assess how well each of these objectives was met. It was also important for me to understand how students of different backgrounds interacted with the course, since METR 200 is a medium-to-large science course for majors and non-majors, with non-majors

making up the majority of students. To complete the following analysis, students were split into six separate academic categories, as described in Table 1.

Table 1: The six academic categories into which students were placed in this study.

Category	Description	Number
1	Meteorology-Climatology major	5
2	Physical science or Engineering major	8
3	Non-physical science major (e.g. psychology)	13
4	Non-science major (e.g. history, journalism)	14
5	Education-related major	17
6	Undecided/unclassified students	5

Category 1, meteorology-climatology majors, generally take METR 200 as the first course in their major sequence. More students with this major take the course in the fall semester, explaining the low number of students in this category. Students with a major in other physical sciences or in engineering were placed in Category 2. These students have usually had significant prior science-related coursework, and often come to METR 200 with a good general grasp of the science concepts learned in more depth and/or in a more applied way in this course. Category 3 students, those with a science major not in the physical sciences, have often not seen many of the concepts learned in METR 200, but are often used to thinking about things in a scientific way. Students with a major not directly related to the sciences were placed in Category 4. These students often come to METR 200 with little prior science experience (they often take the course to fulfill a college-level science requirement), and sometimes little mathematics background. Thus, they often feel uncomfortable in the course and come in with the expectation that they may struggle more than most students. Category 5 accounts for those students with education-related majors. Not all students in this category had a science-related major, but a separate category was created to study specifically those students going into education, since they often make up a large percentage of students in METR 200 (note that, in this semester, they were a larger group than any of the other major classifications). Finally, Category 6 students come to METR 200 with no declared major. These students often fit in one of two categories: either they come with a strong interest in science and do well in the course, or they come with relatively weak motivation and have a lower chance of succeeding.

Alternate student categories could also be analyzed, though this was beyond the scope of this study. Some potentially-insightful categories for breaking down the analysis include student academic year, student initial self-declared interest in science (collected on an initial survey and split into high/medium/low categories), and reason for taking the course (science requirement, personal interest, other).

Some of the analysis shown below was completed in aggregate form—a general overview of how students had improved in their understanding of meteorology concepts was desired, for instance. Many of the analyses, though, are reported for each of the six student categories outlined above. An analysis is presented for how well each objective is being met, and at the end, an analysis of how to identify particularly at-risk students is presented.

## B. Objective 1

The first course objective stated in the syllabus was ***“Develop a good understanding of basic atmospheric properties and processes.”*** Analysis of the meeting of this objective was split into several components.

### 1. Aggregate View of Changes in Concept Understanding

To get a general sense of whether student understanding of basic meteorology concepts improved through the semester, a longitudinal study was performed in which students were asked similar (but in many cases not identical) questions on an initial survey during one of the first class meetings, on one of the exams through the semester, and on the final exam. A total of 10 questions were asked and followed through the semester (see [Appendix B](#), from the initial survey). Results are presented in Table 2.

Table 2: Percentage of students answering each concept question correctly on the initial survey, during the semester on an exam, and on the final exam. Significant improvement highlighted in green.

Question	Initial	Exam	Final Exam	NOTES
a	0%	77.60%	61.11%	Final: fill-in-blank
b	28.00%	79.03%	X	Final--can't judge; question too dissimilar
c	44.23%	69.35%	61.11%	
d	35.29%	89.60%	50.00%	Final: fill-in-blank
e	76.92%	65.52%	72.22%	Exam 2 & final: fill-in-blank (decreased score)
f	82.69%	74.14%	94.44%	Exam 2 & final: T/F
g	38.46%	49.14%	62.04%	Exam 2: work problem (took avg. score--should have been more challenging)
h	46.15%	61.40%	73.15%	Exam 2: work problem (took percent correctly answering 'cold front')
i	0%	18.87%	46.30%	
j	5.77%	37.74%	37.04%	

As seen in Table 2, understanding of most concepts increased from the initial survey to the exam during the semester, and understanding further increased for around half of the concepts tested by the final exam. Two questions (a and i) were answered correctly by no students on the initial survey, but understanding of these concepts increased significant by the during-

semester exam and/or final exam. Most concepts which showed continued improvement on the final exam ([Column 4 of Table 2](#)) were presented later in the semester than those concepts which did not show continued final exam improvement. Questions were asked in different ways at different times. All questions on the initial survey were multiple choice with four answer choices. Thus, questions with very low percentages correct on the initial survey showed student misconceptions, since the percentage correct should be around 25% if students are answering randomly. Concepts were sometimes asked about as a fill-in-the-blank question; these tended to have lower percentages correct because they required students to come up with the response from memory rather than presenting them with a few possible choices. Thus, on a few questions (e.g. questions a, d, and e), scores actually decreased from the initial survey to the during-semester exam, or from the during-semester exam to the final exam.

Overall, I believe these data show a significant increase in understanding of basic meteorology concepts through the semester, averaged over the student population of the course. Percentage of students answering correctly was often greater than 60% on the final exam, with only two questions being answered correctly by less than 50% of participants. Even these lower percentages show significant improvement from the initial survey.

In future work, it may be useful to assess deeper thinking skills and the ability to apply the concepts meaningfully to weather situations. An assessment of these skills at the beginning of the course would likely show no students able to satisfactorily complete a map analysis, for instance, unless they had prior coursework in meteorology or significant personal interest. Longitudinal assessments of these skills could be carried out in METR 200 lab meetings, on in-class quizzes or other activities, and on exams. The ability to meaningfully apply concepts to ongoing weather situations is a key skill I would like to see students come away from METR 200 with, though the development of this skill through time was not assessed.

## **2. Success in Concept Understanding among Academic Categories of Students**

Average score on the three in-class exams was considered a useful measure of concept understanding and the ability to meaningfully apply meteorological concepts. Thus, for each of the six academic categories of students described above (see [Table 1](#)), Pearson's correlation was calculated between average performance on exams and a variety of other factors. The most interesting results from this analysis are presented in Table 3.

Table 3: Correlation coefficients between average score on the three during-semester exams and several other factors.

	A	B	C	D	E	F	G	H	I
Acad. Category	Initial Knowledge Score	Initial Expect. of Course Difficulty	Turn-In Order (avg.)	Hrs/Week Studying (Final Survey)	Particip.	Type of ? (Lecture Questions)	Meetings/ Emails	HW1-4 Avg. Score	HW5 Score
1	-0.34	-0.49	-0.34	0.71	0.67	0.82	X (none)	0.96	0.96
2	0.32	-0.21	0.05	-0.41	0.6	0.17	X (none)	0.81	0.49
3	0.59	-0.36	0.51	-0.3	-0.19	0.5	-0.18	0.9	0.22
4	0.55	-0.25	0.09	-0.58	0.77	0.31	0.17	0.93	0.65
5	0.01	-0.08	-0.05	-0.2	0.63	0.39	0.44	0.63	0.69
6	-0.34	0.82	0.07	-0.93	0.78	X (too few)	0.57	0.91	0.45

Column A relates the number of concept questions correct on the initial survey to average exam scores. More questions correct often meant higher exam scores, but this was especially true among non-physical science majors and non-science majors. This result seems to indicate that student success in groups with less prior formal science exposure may be closely related to individual students' personal level of science knowledge coming into a course. In other student groups, the correlation was weak or even negative.

Column B relates students' initial expectation of course difficulty with average exam scores. Correlation coefficients were generally negative—students who thought the course would be easy also tended to perform well on exams. This finding may reflect the tendency of some METR 200 students to worry that they will not be able to grasp the concepts and complete the mathematical calculations, and then struggle with the material because they are worried. Undecided students (Category 6) did not follow this pattern, but the sample size ( $n = 5$ ) makes it difficult to draw conclusions.

Turn-in order of exams (Column C) was generally unrelated to exam score. The exception was among meteorology-climatology majors, who performed worse on exams if they were turned in later (though a small sample size makes this conclusion less certain) and non-physical science majors (Category 3), who performed significantly better if they turned in their exams later. This finding makes sense, since the non-physical science majors are likely to have reasoned in scientific ways before, but not to have done so for material specific to atmospheric science. Thus, these students should need longer to think through concept application, but should be more likely to apply concepts correctly given sufficient time.



Just prior to the final exam, students reported how many hours per week they spent studying for METR 200 outside of class ([Column D](#)). Generally, students who reported less study time had higher exam scores. This likely reflects a common situation I have seen, when students spend a lot of time reviewing the material but never come to ask questions about it; this tends to reinforce incorrect conceptions. Meteorology-climatology majors ([Category 1](#)), who often have a better grasp of how to apply concepts, seem to benefit more by extra study time. Number of meetings with me and number of emails asking for help with course concepts ([Column G](#)) were positively correlated with higher exam scores in most cases, but especially among students with less prior formal science training ([Categories 4 – 6](#)). Course attendance ([Column E](#)) and average exam score were closely positively correlated, as expected, though this was not true among science majors not focusing on a physical science ([Category 3](#)). Successful students in all categories were generally those who attended class on most days, and who came to ask questions about the material they had trouble understanding.

Through the semester, several opportunities were given for students to write down questions they had on a lecture. [Column F](#) attempts to relate the depth of questions asked to exam scores. Table 4 notes the classifications assigned to these questions.

Table 4: Classifications of student questions about lecture material.

Classification	Description
1	Clarification of something from lecture
2	Question about factual lecture content
3	Question about conceptual lecture content
4	Personal curiosity question related to lecture material
5	"Deeper thought"/application question based on lecture

Classifications were arranged in order of increasingly deep thought about the lecture material. When multiple questions were asked, the value of the highest-classified question was recorded. Examples of responses in each category are presented in [Appendix C](#). Students asking more thoughtful questions also generally received higher exam scores. This indicates that deeper engagement with the material during lectures is critical to developing a meaningful understanding of course content. This appeared to be especially true among meteorology-climatology majors and science majors without a physical science focus.

Conceptual understanding was also built by homework assignments, one of which was given to cover the material on one exam. Average score on the four during-semester homework assignments were strongly positively correlated to average exam score ([Column H](#)), indicating that the reinforcement of concepts by completing homework assignments was truly valuable for learning. Homework 5 had students apply concepts to find examples of weather features in

current data; similar ability to apply was tested on the exams. Correlation between homework 5 score and average exam score (Column I) was lower than for the other homework assignments, but still high.

### 3. Temporal Trends in Student Success at Conceptual Understanding

Students were classified into three groups depending on if their exam scores generally improved, stayed about the same, or generally worsened through the semester. Those students whose scores worsened did not necessarily do poorly on any exams, though their scores declined steadily through the semester. Likewise, students whose scores improved through the semester did not necessarily have any poor exam scores, as long as a steady trend in scores was observed. For each of the three classifications, Pearson's correlation was again calculated between average exam score and the variables included under Section B (Table 3). The most interesting results are shown in Table 5.

Table 5: Correlation coefficients between average score on the three during-semester exams and several other factors, for students whose exam scores generally improved, stayed the same, and worsened.

	A	B	C
Exam Trend	Type of ? (Lecture Questions)	HW1-4 Avg. Score	HW5 Score
Improve (9)	0.81	0.9	0.85
Same (35)	0.21	0.69	0.37
Worsen (12)	0.5	0.69	0.26

Type of questions asked by students in response to several lectures through the semester, as described in Table 4, was closely associated with the trend in student exam performance (Column A). Students whose exam scores were higher and improved through the semester generally asked particularly thoughtful questions. Students with high and improving scores also tended to do very well on homework assignments designed to increase conceptual understanding by repeat exposure to concepts (Column B). Particularly noticeable, those students with high and improving exam scores tended to do especially well on Homework 5 (Column C), an assignment meant to give students practice at applying course concepts to current weather data.

#### 4. Overall Assessment of Student Conceptual Understanding

To quantitatively assess overall student understanding resulting from the course, a measure was created which consisted of 50% the average score on the during-semester exams, and 50% the final exam score. Then, the standard grading scale (e.g. 90%+ = A) was applied to the resulting percentages to determine how many students had a very high, high, average, low, or non-passing overall understanding of course concepts. Results are presented in Table 6.

Table 6: Percentage of students demonstrating very high, high, average, low, and non-passing understanding of course concepts, for each academic student classification. Green shading indicates good performance relative to the class average, while red shading indicates poor relative performance.

Acad. Category	Very High (A)	High (B)	Avg (C)	Low Pass (D)	Fail (F)
1	0%	20%	40%	0%	40%
2	13%	63%	13%	13%	0%
3	8%	17%	33%	33%	8%
4	0%	17%	8%	50%	25%
5	0%	41%	24%	6%	29%
6	0%	0%	0%	40%	60%
TOTAL	3.3%	28.8%	20.3%	23.7%	23.7%

Though exams were written to be quite challenging, I would have expected more than 3.3% of students overall to obtain a very high (A) level of understanding, as measured by exam scores. A reasonable number of students received high (B) and average (C) overall exam scores, though I would have liked to see some of the low (D) and no-pass (F) students in this range. A higher percentage of students received low and no-pass overall exam scores than what was considered optimal. This seems to reflect the difficulty students often had with applying course concepts (rather than memorizing information). In the future, more examples of application-based problems should be given in an attempt to improve student exam scores (or, in other words, to help students develop greater proficiency with course concept application).

Shaded cells in Table 6 indicate groups of students which tended to have a better conceptual grasp than average (green cells) or poorer grasp than average (red cells). Physical science majors, not surprisingly, tended to display a higher-than-average level of conceptual understanding. Non-science majors, undeclared students, and meteorology-climatology majors displayed lower-than-average conceptual understanding, though total students in the latter two categories were quite small. This analysis indicates that special attempts should be made to reach out to non-science majors, and to undeclared students.

### C. Objective 2

The second course objective was to ***“Develop the ability to interpret meteorological data, draw appropriate inferences from it, and apply meteorological concepts to new weather situations.”*** Analysis of how well this objective was attained was again based on several course assessment instruments.

On Homework 4, a question was asked which required students to assess a severe weather situation and decide what to tell emergency managers based on the information given (see [Appendix D](#)). Sections b and c of this question were worth 5 total points. A ‘high’ level of meeting this objective was assigned to students who received 4.5 – 5 of the points, a ‘medium’ level for 2.5 – 4 points, and a ‘low’ level for < 2.5 points. Percentage of students meeting this objective at high, medium, and low levels are presented in Table 7 for the academic categories defined in [Table 1](#). High and low examples are also presented in [Appendix D](#).

Table 7: Percentage of students in each academic category meeting Objective 2 at a high, medium, and low level on an applicable Homework 4 question.

Acad. Category	High	Mid	Low	Avg.
1	100%	0%	0%	3
2	88%	12%	0%	2.88
3	75%	17%	8%	2.67
4	45%	55%	0%	2.45
5	75%	19%	6%	2.69
6	50%	50%	0%	2.5
TOTAL	71%	25%	4%	2.67

Again, green shading indicates classifications of students who did significantly better than average, and red shading indicates student groupings with significantly lower-than-average attainment of this objective. Meteorology-climatology majors and other physical science majors performed substantially better than average, while non-science majors and undeclared students struggled. Overall, having 71% of students satisfy this objective at a high level was considered satisfactory.

One question on the final exam had students applying course concepts to a new, real weather situation (see [Appendix E](#)). This assessment was designed to cumulatively test students’ ability to meaningfully apply what was learned throughout the semester, and to make several predictions using the data available. Student scores on these questions were again classified as very high, high, mid, low-pass, and no-pass attainment of Objective 2. Percentages of students

in each attainment category are presented in Table 8. Two examples of work on this final exam question, one very high and one low-pass, are also presented in [Appendix E](#).

Table 8: Percentage of students in each academic category meeting Objective 2 at a high, medium, and low level on applicable final exam question. 'Average' column gives the average score on these questions, out of a total of 25 possible points.

Acad. Category	Very High	High	Mid	Low	No Pass	Average
1	0%	0%	50%	50%	0%	12.88
2	13%	50%	25%	13%	0%	17.38
3	25%	17%	33%	17%	8%	15.92
4	9%	18%	45%	9%	18%	13.77
5	6%	19%	25%	6%	44%	12.06
6	0%	33%	0%	33%	33%	11.67
TOTAL	11%	20%	33%	15%	20%	14.09

Attainment of Objective 2 at a high level was lower than for the Homework 4 questions discussed above, for a few reasons. Since the exam was in-class and the homework was out-of-class, lower attainment would be expected on the final exam. The final exam questions were also made significantly more challenging, so lower scores were anticipated.

Only 11% of students reached very high attainment of Objective 2 on the final exam. Category 3 students, those with science majors not in the physical sciences, were surprisingly the only group with a significantly higher attainment. High attainment of Objective 2 was demonstrated by fully half of the physical science majors (Category 2), a result not unexpected given this group's prior exposure to science concepts and reasoning. Relatively low attainment of Objective 2 was demonstrated by meteorology-climatology majors, education-related majors, and undeclared students, though the first and last of these categories were only represented by a small sample of students. Overall, the 64% of students demonstrating a mid, high, or very high attainment of Objective 2 on the final exam was considered a good result. In the future, fewer students will hopefully populate the 'no pass' category, given additional example problems of the type of analysis expected on the final exam.

Homework 5 required students to look at current weather data, find examples of weather features in the data, and to write a short sentence about how the weather feature affected local weather (see [Appendix F](#)). Thus, how well students were able to fulfill the requirements of Homework 5 was also seen as a means of assessing attainment of Objective 2. Final scores on Homework 5 were split into several classifications describing level of attainment of Objective 2: very high attainment (95%+), high attainment (87% - 94.9%), mid attainment (80% - 86.9%), low attainment (60% - 79.9%), and very low/no-pass attainment (< 60%). Six scores of zero

were assigned on this homework, though four of these were due to cheating. Percentages of students in each attainment category are presented in Table 9.

Table 9: Percentage of students in each academic category meeting Objective 2 at various levels on Homework 5. 'Average' column gives the average score on these questions, and 'Avg. minus zeros' column shows the average score calculated with zeros removed.

Acad. Category	Very	High	Mid	Low	No Pass	Average	Avg. Minus Zeros
1	25%	50%	0%	0%	25%	71.7%	95.6%
2	13%	13%	50%	26%	0%	81.9%	81.9%
3	42%	17%	25%	8%	8%	82.9%	90.4%
4	18%	45%	18%	9%	9%	80.9%	89.0%
5	41%	29%	12%	0%	18%	78.6%	89.1%
6	25%	0%	50%	0%	25%	66.3%	88.3%
TOTAL	30%	27%	23%	7%	13%	79.1%	88.6%

80% of students attained Objective 2 with this assignment at a medium level or higher; this was considered a very good result. Meteorology-climatology majors and science majors not in the physical sciences did particularly well, while science majors in the physical sciences did relatively poorly. This may be because many of the students in Category 2 already had relatively high grades in the course, and since Homework 5 was due at the end of the semester, less effort may have been spent on doing this assignment well. Supporting this possibility, more Category 2 students did better on the final exam than on Homework 5, than for students in any of the other academic categories.

#### D. Objective 3

The third course objective was to have students ***“Think and write critically and scientifically about weather events, and be able to assess the scientific validity of content.”*** Analysis of how well this objective was met was based on only one measure; assessment of this objective needs strengthening in the future if it is to be retained.

Homework 6, as Homework 5, was assigned near the beginning of the semester and due by the final exam. This assignment had students find a scientific journal article or a news article of interest, write about the science in the article, and offer a critique of how well-constructed the article was (see [Appendix G](#)). This assignment was graded on the quality of analysis and the quality of writing separately, so the two components of Objective 3 (critical/scientific thinking and writing) could be assessed using these two scores. Table 10 shows the average scores in these two areas for students in each of the academic categories described in Table 1. [Appendix G](#) also contains two examples of high to very high papers and one example of a low paper.

Table 10: Average analysis and writing scores for students in each of the academic categories. Green-shaded cells show a significant positive departure from average, while red shading indicates a substantial negative departure from average. Remaining columns show percentages of students attaining Objective 3 at a very high, high, medium, and low level, with color shading again indicating student categories performing significantly higher (green) or lower (red) than the class average.

Acad. Category	Avg. Analysis	Avg. Writing	Analysis				Writing			
			Very High	High	Mid	Low	Very High	High	Mid	Low
1	53.25	33.75	25%	50%	25%	0%	0%	50%	25%	25%
2	52.5	35	25%	25%	50%	0%	13%	50%	13%	25%
3	52.36	35	27%	27%	45%	0%	27%	27%	36%	9%
4	50.27	35.36	9%	9%	64%	18%	36%	36%	18%	9%
5	51.44	33.81	6%	38%	56%	0%	6%	31%	44%	19%
6	47	32.25	0%	0%	100%	0%	0%	0%	50%	50%
	51.52	34.51	15.40%	26.90%	53.80%	3.80%	17.30%	34.60%	30.80%	17.30%

Critical thinking resulting from the chosen article was assessed by the quality of student analysis. This analysis required students to think about the science in their article and relate it to course material, and if students chose a news article, to think about the scientifically valid or weak points of the article. Highest attainment of the analysis objective was generally achieved by meteorology-climatology majors, other physical science majors, and science majors not in a physical science area. These categories had higher-than-average analysis scores and larger percentages of students with a very high attainment of this objective. Non-science majors and undeclared students clearly struggled most with this assignment, as might be expected given their lack of prior scientific analysis of research or news articles in a formal setting. This result suggests that these student groups may need additional help with the process of scientific analysis. Such help could possibly be provided by going through an example or two in class, and by giving a few short writings to analyze in lab and/or on homework assignments. Overall, approximately 96% of students in the course attained this objective at a medium or higher level, which was considered very satisfactory. In the future, I would like to see more students in the lower-attainment groups with higher analysis scores.

Objective 3 also addresses the ability to write critically and scientifically. Homework 6 was assigned a separate writing score designed to measure quality of writing in the article summary and critique. Category 4 students (those with non-science majors) had the highest average writing score, despite a weak analysis component. This can possibly be attributed to the writing emphasis in many non-science courses: presumably these students have had significant prior formal writing practice, so came to METR 200 better-equipped to express their ideas well in writing. Physical science majors, undeclared students, and students whose major was related

to education tended to have lower writing scores than I consider optimal. In the future, it may be helpful to include multiple short writing assignments through the semester, with some feedback along the way about how to improve writing. This type of exercise is difficult to include in a course such as METR 200 given the typically-large number of students, but seems to have value since this is the only science course many of these students will take in college.

One challenge of assessing attainment of this objective is the lack of a second data-point, which could be used to show growth in this area. In the future, if this objective is to be retained, the assessment and teaching strategy addressing this objective should be strengthened.

#### E. Objective 4

As the fourth course objective, it was stated that students should ***“Appreciate the complexity of daily weather and the climate system, and apply course material to your observations of the natural world.”*** This objective is more difficult to assess because of the less-quantitative available measures. Student feedback has been sufficient, however, to conclude that this objective was attained by a majority of students in the course.

Many students, especially meteorology-climatology majors, other physical science majors, and education majors, came to talk to me through the semester about their meteorological observations. Conversations that stand out include student observations of thunderstorm shelf clouds and advection fog over Lake Superior during the early summer. A few education majors asked questions about specific topics and requested places to look for further information, as they were interested in those topics and wanted to share them with future students.

When students were given opportunities to ask questions after several of the lectures, they often wrote about personal observations related to the lecture material. Over the semester, this was observed with roughly a quarter of students. Examples of student observations and questions related to lecture include the following:

“Why is there a “calm” before the storm?”

“What causes the greenish tint in some storm clouds?”

“Is this current stream of cold weather due to an excess of aerosols?”

“When talking about Milankovitch cycles does that contribute to the odd winter and spring that we have had even though it has not been the “severe” season?”



Finally, on a survey given a few days prior to the final exam, students were asked if and how they would use course material after leaving METR 200. The following choices were available:

- A) Applications to day-to-day weather events around me
- B) Applications to other coursework
- C) Other: \_\_\_\_\_ (open-ended)

Table 11 shows the percentage of students in each academic category who answered each of the possible choices on this question.

Table 11: Student uses of METR 200 material after the course is completed.

Acad. Category	A	B	other	none
1	100%	75%	0%	0%
2	100%	50%	13%	0%
3	80%	20%	10%	0%
4	91%	9%	18%	0%
5	100%	13%	7%	0%
6	67%	0%	0%	33%
Total	92%	24%	10%	2%

A surprising number of students (92% of those who took the survey) reported that they would use course material to understand day-to-day weather events (Column A). Meteorology-climatology majors, other physical science majors, and education-related majors were especially likely to use the information in this way. It was especially encouraging to see education-related majors wanting to apply their knowledge to everyday situations, as they will hopefully have an opportunity to pass this enthusiasm down to future students. Approximately a quarter of students said they would use what they learned in METR 200 in other coursework (Column B). This percentage was highest among meteorology-climatology majors, as expected, but also quite high (50%) among other physical science majors. Not surprisingly, non-science majors were not likely to use METR 200 material in other coursework, but many of these students did report that they would use the material to understand daily weather events. Only one student reported that they would not use METR 200 material in the future. Overall, these results were considered very positive. In the future, it may be useful to show students how what they learn in METR 200 may be helpful in their future coursework. As part of this survey, participants were also given an opportunity to state how they would use course material under “Other” (Column C). Representative responses were:

“Planning hiking/checking weather systems.”

“I work at Outdoor Adventures and will use my knowledge of weather for outdoor trips, storm safety, and weather preparedness.”

“I may use this in my future, when flying for the Air Force.”

“Basic weather understanding applicable to reporting.”

It was encouraging to see this variety of future uses of METR 200 material, which included personal knowledge of ongoing weather, weather safety for groups, help in an aviation-related career, and understanding applicable to a journalism-related career. A goal of METR 200 is for the material to be applicable for students with a large variety of backgrounds, and it appears this has been the case. Future course content may emphasize how course material may be useful to students in a wide variety of disciplines.

#### **F. Identification of Particularly At-risk Students**

From the first several lectures until the final exam, a total of eight students either withdrew from METR 200 or quit attending. Three additional students continued attending through the semester, but received a low grade (D+ or lower). Some brief analysis was conducted to see if there may have been warning signs that these students were particularly at risk. If students especially at risk of withdrawing or receiving a low grade could be identified in advance, special intervention could possibly help these students be more comfortable with course material. Also, these students frequently did not communicate with the instructor, so this could be encouraged earlier in the semester if particularly at-risk students were identified. Table 12 summarizes the characteristics of the students who withdrew or received a low grade.

Table 12: Characteristics of students leaving METR 200 prior to the end of the semester, or receiving a low final grade (D+ or lower). Red shading highlights categories with a high percentage of at-risk students.

Acad. Category	#	Male	% Turn in 1st Survey
1	2	100%	100%
2	0	NA	NA
3	1	100%	100%
4	3	100%	67%
5	2	0%	0%
6	3	100%	67%
Total	11	82%	64%

Number of at-risk students was particularly high among meteorology-climatology majors (2 of 5 total students) and undeclared students (3 of 5 total students). Non-science majors were also especially likely to leave the course prior to the final exam. Physical science majors not in meteorology-climatology did not leave the course or receive low grades, despite a high number of students in this category. Poor performance among meteorology-climatology majors can sometimes be attributed to unrealistic expectations entering the course—many aspiring majors are either unprepared for the rigor of the course, or think meteorology is mostly about storm chasing. Non-science majors, who have not had prior exposure to as much science coursework, likely find the course conceptually very challenging and thus are more likely to withdraw. Undeclared students often lack motivation to succeed in METR 200. It is unclear whether this is a result of weak prior preparation, the lack of a clear educational plan, or some other factor.

A few other factors were noted as particularly unique among the at-risk students. First, a large majority (82%) were male. Of the six academic categories defined, in fact, five had at-risk students, and in four of the categories, all at-risk students were male. The exception was education-related majors, in which both at-risk students were female. This observation may simply reflect the fact that only 24% of students in this category were male, the lowest percentage for any of the academic categories. Regardless, there appears to be a genuine preference for at-risk students to be male. One contributor may be that male students are less likely to ask for help with course concepts: while 60% of students asking for help during the semester were female, only 29% of those not asking for help were female. The final column of Table 12 shows the percentage of students turning in an initial survey at the beginning of METR 200. While 87% of successful students turned in a survey, only 64% of at-risk students turned in the survey. Thus, students who start the class relatively unengaged seem less likely to be successful. In some cases, these students are not willing to become engaged with class material, while some others may respond to an early reaching out by the instructor.

Other possible signs of at-risk students were sought from the initial course survey and the mid-semester survey. Differences were sought between the average responses of the at-risk group and the average of all student responses. The most significant findings are included in Table 13.

Table 13: Findings of significant differences between the average of at-risk student scores and the average of all student scores on the initial and mid-semester surveys.

First Survey	Category	Lecture Understanding	Exp. Diff. of METR 200	Science Interest
	All students	6.56	6.02	6.29
	At-risk students	6	6.43	5.71
Mid-Semester Survey	Category	Lecture Understanding	Diff. of METR 200	Hrs/Week Studying
	All students	6.26	7	3.44
	At-risk students	5.5	7.5	2.25

On the initial survey, given after students had attended several lectures, at-risk students reported a significantly lower understanding of those lectures than the class average. They also expected METR 200 to be more difficult, possibly indicating an inherent fear of science coursework often seen in students who struggle in introductory meteorology. A question on the initial survey also asked participants their interest in science in general, and the at-risk students reported a significantly lower average science interest than the class average. These three factors, then, may be helpful for early identification of especially at-risk students.

Fewer students were present by the mid-semester survey, but there were still significant differences between at-risk students who remained in the class and their peers. Understanding of lectures had decreased more in the at-risk group, and was now quite lower than the class average. At-risk students reported METR 200 was quite difficult for them, and of interest, also reported significantly less study hours per week than the students who would be successful. It is not known if the lack of study time among at-risk students is a result of low motivation to study, or of frustration at not understanding the material. Regardless, these three factors may be useful for distinguishing at-risk students who remain in the class by mid-semester.

## VI. Summary and Planned Changes to METR 200

Overall, student work provides evidence that course objectives were attained by a large majority of students in METR 200. Work was generally of particularly high quality among science majors. The distribution of objective attainment across student academic categories generally meets my goals for the course, though I would like to see non-science majors and undeclared students perform at a higher level. These students may need special help and encouragement to improve their level of success.

Students mostly appear to be prepared for other coursework by their METR 200 experience. Meteorology-climatology majors especially need this material in future coursework. 60% of these students attained the course objectives at a satisfactory level and should be well-prepared for future coursework. Of the 40% who did not, representing two students, one quit attending and the other turned in poor-quality work. It is doubtful that the student who quit attending could have been convinced to remain in the class (conversation with this student, and the offer of help, were not successful). The other student may have responded to aggressive offers of help, but was not generally interested in being helped with course material. Other physical science majors appear to have generally done very well with METR 200 and should be well-prepared for future scientific reasoning; half of these students reported they would use the course in further coursework. Other students in the course may be less likely to use METR 200 in future coursework, but most said they would use what they learned to interpret daily weather events, so this is considered a sufficient success.

Several changes are suggested for future sections of METR 200, which should help to increase the percentage and level of course objective attainment among students as a whole and non-science majors and undeclared students in particular:

- More routinely assess the ability to apply course concepts meaningfully to weather situations, in lab meetings, during in-class activities, and as part of homework assignments. More frequent guided application exercises would help students develop the critical thinking skills desired as an outcome of METR 200, and would help the instructor more efficiently judge how students are developing in this area. Students should also be more likely to use course material once they have left METR 200 if they have seen repeated examples of how the course material may be used in the analysis of day-to-day weather situations.
- Include multiple short writing assignments through the semester, with feedback along the way about how to improve writing. This addition will strengthen the writing development component of the course, and will be helpful to students in their other coursework. It will also prepare students to be successful in their writing an analysis of a scientific journal article or news article.
- Include a second data-point to assess development in critical thinking and scientific writing skills. An additional exercise of this sort will give students additional feedback in these areas, will give them an opportunity to learn and improve, and will help the instructor in assessing how well this objective has been met.
- Lead students through a series of short articles with varying degrees of scientific accuracy, discussing as a group or in small groups their scientifically valid points and points needing improvement. These exercises could expose students to several topics related to the atmospheric sciences and weather impacts. They would also make class

meetings more interactive, and would prepare students for one of their end-of-semester assignments in which they write a critique of an article with scientific content.

- Show students how what they learn in METR 200 may be helpful in their future coursework, and how METR 200 material may be applied to a wide range of disciplines. This should be valuable as a motivator, if students can see applicability of course material to their personal interests. Presentation of this material could take the form of additions to existing lectures, short discussions with the whole class, and/or individual group discussions during class meetings and/or during lab.

## VII. Assessment of the Portfolio Process

The process of creating this course portfolio has helped me get a better sense of why, in the past, certain course elements appeared to not be working as well as they should. I have been able to identify several areas where course activities were not adequately supporting objectives, and have put much more thought into how attainment of the objectives should be assessed (and how this can be done better in the future). I have also been able to identify specific groups of students that struggle in particular areas, and feel better-equipped to reach out to struggling future students with appropriate help. Overall, creating this course portfolio has been a valuable learning experience, and I plan to continue utilizing the methods I've learned through the Peer Review of Teaching program in my other coursework at all levels.

# Appendix A: Course Syllabus

## METR 200-150 – Weather and Climate

### Syllabus: Spring 2013

**Lecture:** TR 9:30 – 10:45 AM, Teachers College 105

**Instructor:** Matthew Van Den Broeke (mvandenbroeke2@UNL.edu)

**Office:** Bessey Hall 306 **Office**

**Hours:** T 10:45 – 11:45, F 2:30 – 3:30; others by appt. (email me)

**Course Assistants:** Gabriel Lojero ([GALojero@gmail.com](mailto:GALojero@gmail.com))

Sarah Mustered ([Sarah.Mustered@Huskers.UNL.edu](mailto:Sarah.Mustered@Huskers.UNL.edu))

#### Course Content:

This course is designed to provide an introductory survey of atmospheric science for majors and non-majors, including study of weather and climate elements and their distributions, weather data and its application, basic weather forecasting concepts, midlatitude weather systems and their effects, and the global climate system with examples of its variability. Basic college-level mathematics is assumed. You should also be enrolled in the corresponding laboratory section.

#### Course Goals:

METR 200 is an ACE 4 class, the purpose of which is to “use scientific methods and knowledge of the natural and physical world to address problems through inquiry, interpretation, analysis, and the making of inferences from data, to determine whether conclusions or solutions are reasonable.” To this end, we will seek to fulfill the following goals in this course:

- 1) Develop a good understanding of basic atmospheric properties and processes.
- 2) Develop the ability to interpret meteorological data, draw appropriate inferences from it, and apply meteorological concepts to new weather situations.
- 3) Think and write critically and scientifically about weather events, and be able to assess the scientific validity of content.
- 4) Appreciate the complexity of daily weather and the climate system, and apply course material to your observations of the natural world.

**Textbook:** Weather Studies: Introduction to Atmospheric Science (5<sup>th</sup> ed.), AMS.

Textbook Website: <http://www.ametsoc.org/amstedu/login.cfm>

**Lab Manual:** Investigations Manual: Weather Studies. AMS.

#### Course Policies:

**Environment:** I expect the class environment to be interactive, professional, and challenging. At the same time, I hope we can have fun learning meteorology together. Students are expected to arrive on time, to use laptops only for course work, and to have cell phones off or silenced.

**Late Policy:** Your work should be turned in by the due date. If it is not, you will receive a zero. I will be understanding of emergencies that may come up—in all cases, please communicate with me. If possible, please let me know prior to class via email or in person if you are unable to turn in an assignment on time—we may be able to make other arrangements.

**Lecture Notes:** These will be posted on our course Blackboard page. If it's your style of learning, you may find it helpful to print these out before lectures and fill them in as we go through the material.

**Help with the Course:** As your instructor, I want to see you do well in this course. If you have any questions about the material, homework, etc., see me before or after class, send me email anytime (which is the best way to communicate with me), or come to office hours. If more time is needed we can make arrangements to meet and discuss what you're having trouble with. *I expect you to take an active role in making sure you understand the course material!*

**Grades** will be posted on Blackboard (my.unl.edu). I will also use Blackboard to post materials such as homework assignments, handouts, and review sheets.

**Course Assessment:**

Exams 1, 2, & 3	10% each
Final Exam	20%
Homework	20%
Quizzes and Participation	10%
Laboratory Section	20%

**Exams** are designed to test your knowledge of course material and your ability to apply it meaningfully to new weather situations. The final exam will be cumulative, with 40% - 50% of questions coming from the last section of course material. Exams must be taken on the scheduled date—if this is not possible, please talk to me *before* the exam. In rare cases I may be able to let you take the exam on an alternate date. Review sessions will be held at the end of the last class before each exam, and a review sheet will be available on Blackboard.

**Homework** assignments will be varied in length and form. Some questions will help you learn the concepts, while others will take you deeper into the theory and concept application. Some assignments will let you explore areas of personal interest. 6 assignments will be given—2 early in the semester and due at end, and 4 as we are discussing appropriate material. All homework scores are retained for your final grade. *It is expected that all work and writing you turn in represents **your own** thought (there will be grade penalties if not)*, though working with other students is encouraged. Homework will be helpful as you study for exams. A help session will be held after the class prior to each homework due date. Homework solutions will be posted after your assignments are turned in.



**Quizzes** are unannounced, will occur on random days at the beginning or end of class, and will cover concepts from the past lecture or two. Their main purpose is to reward people who come to class on time. 5 quizzes will be given through the semester, and all will be retained in the calculation of a final grade. No make-up quizzes are allowed, unless the student is absent for an approved reason. Additional activities and attendance checks may also count in the **participation** grade.

The **Laboratory Section** will be conducted at the scheduled time outside of our regular lecture meeting. Your laboratory instructor will set the policies for lab, including grading. You are required to earn a passing grade ( $\geq 60\%$ ) in your lab section to pass METR 200.

The **grading scheme** for this course will approximately follow the following scale (grades are guaranteed if your percentage is within these ranges):

<b>A+</b>	97.5+	<b>B+</b>	87.5 - 89.99	<b>C+</b>	77.5 - 79.99	<b>D+</b>	67.5 - 69.99
<b>A</b>	92.5 - 97.49	<b>B</b>	82.5 - 87.49	<b>C</b>	72.5 - 77.49	<b>D</b>	62.5 - 67.49
<b>A-</b>	90 - 92.49	<b>B-</b>	80 - 82.49	<b>C-</b>	70 - 72.49	<b>D-</b>	60 - 62.49

**Academic Honesty:** Any instance of academic dishonesty will be taken seriously, and substantial penalties will be levied. For UNL's student conduct code, see: (<http://stuafs.unl.edu/ja/code/>).

**Reasonable Accommodation:** UNL is committed to providing reasonable accommodation for students with disabilities. Students requiring accommodation in this course should talk to me as soon as possible. In addition, you must be registered with the Office of Services for Students with Disabilities. Also see <http://www.unl.edu/ssd>.

In this course it's my hope that we can have some fun learning about many interesting weather events, and that you will gain greater appreciation for the processes leading to what we see every day as weather. I also hope this course will build your critical thinking skills in a way applicable to other coursework, and to life in general. And always, if you have questions about anything in meteorology, please ask!

**Tentative Schedule (Subject to minor changes)**

<b>Date</b>	<b>Topic</b>	<b>Reading Assignment</b>	<b>Work Due</b>
8 Jan	Lecture 1: Introduction & Properties of the Atmosphere	none	
10 Jan	Lecture 2: Heat and Earth's Energy Budget	pgs. 4 – 12, 46 – 49, 108 – 128	Memorize the states
15 Jan	Lecture 3: Temperature Distribution and Measurement	pgs. 64 – 92	
17 Jan	Lecture 4: Pressure, Forces, and Force Balances	pgs. 143 – 154, 249 – 265	
22 Jan	Lecture 5: Surface Weather Observations	pgs. 39 – 40, 442 – 443	
24 Jan	Lecture 6: Upper Air Maps and Vorticity; Map Discussion	pgs. 42 – 45, 444	
29 Jan	Lecture 7: Other Meteorological Observations and Simulations	pgs. 13–18, 229–235, 272, 445–462	
31 Jan	Lecture 8: Moisture, Adiabatic Processes, Stability; Exam 1 Review	pgs. 168-188, 154; Bring questions!	Homework 1
5 Feb	EXAM 1 (Covers lectures 1 – 7)	none	
7 Feb	Lecture 9: Condensation and Clouds	pgs. 206 – 218	
12 Feb	Lecture 10: Precipitation Types and Forecasting	pgs. 219 – 228	
14 Feb	Lecture 11: The Global Circulation and Local Winds	pgs. 280 – 289, 343 – 348	
19 Feb	Lecture 12: Westerly Waves and their Effects	pgs. 290 – 294, 296 – 312	
21 Feb	Lecture 13: Air Masses and Fronts	pgs. 323 – 330	
26 Feb	Lecture 14: Development of Highs and Lows; Exam 2 Review	pgs. 295, 331 - 332; Bring questions!	Homework 2
28 Feb	EXAM 2 (Covers lectures 8 – 13)	none	
5 Mar	Lecture 15: Midlatitude Cyclones	pgs. 333 – 342, 355 – 357	
7 Mar	Lecture 16: Cold Waves, Lake-effect Precipitation, and Blizzards	pgs. 269 – 271	
12 Mar	Lecture 17: Mountain Meteorology	pgs. 358 – 360	
14 Mar	Lecture 18: Thunderstorm Overview, Airmass Storms, Multicells	pgs. 364 – 372	
19 Mar	NO CLASS: Spring Break	none	
21 Mar	NO CLASS: Spring Break	none	
26 Mar	Lecture 19: MCSs and Squall Lines	pgs. 378 – 380	
28 Mar	Lecture 20: Downbursts, Microbursts, and Heatbursts; Exam 2 Review	pgs. 349, 376 – 377	
2 Apr	Lecture 21: Supercells; Exam 3 Review	none; Bring questions!	Homework 3
4 Apr	EXAM 3 (Covers lectures 14 – 20)	none	
9 Apr	Lecture 22: Hailstorms and Lightning	pgs. 373 – 375, 381 – 383	
11 Apr	Lecture 23: Tornadoes	pgs. 384 – 392, 401 – 402	
16 Apr	Lecture 24: Tropical Cyclones	pgs. 406 – 429	
18 Apr	Lecture 25: Air Pollution and Effects	none	
23 Apr	Lecture 26: Climate Controls, Feedbacks, and Recent Change	pgs. 495 – 497, 503 – 530	
25 Apr	Lecture 27: Climate Classification; Final Exam Review	pgs. 498 - 503; Bring questions!	Homework 4

**Final Exam: Tuesday, 30 April, 10 AM – 12 PM, TEAC 105 (Homework 5 and 6 are due at the Final Exam, but can be turned in anytime earlier)**

## Appendix B: Ten Knowledge Questions from 1<sup>st</sup> Survey

1) Choose the best answer for the following multiple choice questions:

- a) If water is completely pure, it will freeze at approximately:  
A) -20 °C      B) -2 °C    C) 0 °C      D) -40 °C
- b) If you wanted to forecast a likely location for a storm this afternoon, which model would you use?  
A) ECMWF      B) GFS      C) GEM      D) RAP
- c) Which radar variable indicates air moving toward or away from the radar?  
A) Reflectivity factor      C) Differential reflectivity  
B) Radial velocity      D) Storm-relative radial velocity
- d) What phase change of water occurs when a patch of ice disappears from the sidewalk over several very cold days?  
A) Deposition    B) Melting      C) Evaporation    D) Sublimation
- e) Which variable represents the temperature to which the air must cool to become saturated?  
A) Convective temperature      C) Mixing ratio  
B) Dewpoint temperature      D) Relative humidity
- f) Which is most likely to be true if a parcel is rising through the atmosphere?  
A) The parcel is warmer than its environment  
B) The parcel is the same temperature as its environment  
C) The parcel is cooler than its environment
- g) A moist parcel starts out at sea level. What is true about the parcel after it rises over a mountain and comes down the other side? *Choose all that apply.*  
A) The parcel is warmer    C) The parcel is moister  
B) The parcel is cooler    D) The parcel is drier
- h) The passage of which boundary is characterized by the arrival of drier air and a wind shift to the northwest?  
A) Dryline      B) Occluded front      C) Cold front      D) Warm front
- i) What is the name of energy transferred directly to the air by a warm surface?  
A) Directional heat    B) Latent heat      C) Radiational heat    D) Sensible heat
- j) Upper-level divergence less than low-level convergence in a cyclone best describes:  
A) Intensification    B) Cyclogenesis      C) Occlusion      D) Filling

# Appendix C: Examples of Lecture Questions in Each of the Five Categories

Table 4 defines the five categories of questions asked by students in response to the lectures:

Classification	Description
1	Clarification of something from lecture
2	Question about factual lecture content
3	Question about conceptual lecture content
4	Personal curiosity question related to lecture material
5	"Deeper thought"/application question based on lecture

The following are examples of questions in each of the categories.

## Category 1: Clarification

"What does MCS stand for?"

## Category 2: Factual Content

"I didn't understand how to identify bow echoes and derechos on radar."

"Will the anvil always occur in a squall line cross section?"

## Category 3: Conceptual Content

"How is the MCS different from an extratropical cyclone?"

"Is a bow echo its own MCS structure or a type of squall line?"

## Category 4: Personal Curiosity

"How often does a comma cloud's tail line actually end up being a squall line?"

"What is happening in a storm that causes it to be calm right before the storm hits"

## Category 5: Deeper Thought/Application

"What causes a microburst? Does it come from a storm or is it completely independent of storms?"

"If a lack of MCSs result in a drought, will an excess of MCSs result in flooding?"

## Appendix D: Questions from Homework 4 Used to Assess Interpretation of Meteorological Information, with Examples of Student Work

**11) On a warm spring morning, the CAPE value is  $2470 \text{ J kg}^{-1}$ , and storm-relative helicity is  $209 \text{ m}^2\text{s}^{-2}$ .**

**b) You are a forecaster and were given just the information above. List 4 additional pieces of information you would want to assess more fully the severe weather threat for later in the afternoon and evening, and briefly describe what each would tell you.**

*A good (high) answer:*

"On an EHI scale 3 means that there is a potential for a tornado. To conclude if this is a true possibility I would look at a 300 mb [map] to look for divergence which would indicate a surface low. I would check a surface map and look for high wind shear which would aid updraft. I would look at a sounding to see how much moisture was in the air and look for increasing humidity which helps thunderstorms form."

*A poor (low) answer:*

"Mesocyclone: thunderstorm with rotating updraft. Heavy precipitation: hail, rain. Downdraft structure: FFD and RFD. Vertical wind shear: causes storm to tilt."

**c) The day is sunny with an increasing dewpoint, and a model indicates thunderstorms and a strengthening low-level jet after sunset. Given the information in (a), what is your forecast regarding potential for tornadic storms? What do you tell emergency managers in your area?**

*A good (high) answer:*

"If the dewpoint is increasing, then instability (CAPE) is likely to increase. A strengthening of the LLJ could cause wind shear at low levels, which is essential for the formation of tornadic storms. Based on this information, I would say there is a moderate to high potential for tornadic storms. I would tell emergency managers to be prepared to sound warnings for tornadoes, and I might recommend a tornado watch status."

*A poor (low) answer:*

"low chance, thunderstorm watch, maybe tornado watch"

# Appendix E: Final Exam Questions Used to Assess Ability to Interpret and Apply Meteorological Data, with Examples of Student Work

## 8) *Air Masses, Frontal Boundaries, and Midlatitude Cyclones (required)*

On 10 February 2013, a powerful midlatitude cyclone traveled across North America. You will analyze some data from this case.

a) Using the surface map (on the data sheet at the end of the exam), which contains temperature, dewpoint, and wind information at many stations across the central United States, complete the following analysis:

- 1) Label the low pressure center with an 'L'.
- 2) Draw the cold front, warm front, and dryline with proper symbols.
- 3) Label the 4 air masses which occur around the low (e.g. mT).
- 4) What type of cyclone is this? \_\_\_\_\_
- 5) Does freezing rain seem likely north of the warm front of this cyclone? Briefly justify your response.

6) Does a blizzard look likely with this cyclone? If so, where would it be located?

7) The temperature in Scottsbluff, Nebraska (far western NE) is currently 31°F. What is a reasonable temperature for this air by the time it reaches northern Oklahoma?

8) Assess the potential for mountain snow along the foothills of the Rocky Mountains, from eastern Wyoming south to eastern New Mexico.

9) Assess the potential for lake-effect snow around Lake Michigan. Briefly justify your assessment.

b) How do you expect the temperature, dewpoint, and wind direction to change at the following locations in the next 6 – 12 hours (think about frontal passages)?

1) Galena, IL (the far northwest corner of Illinois):

Temperature:

Dewpoint:

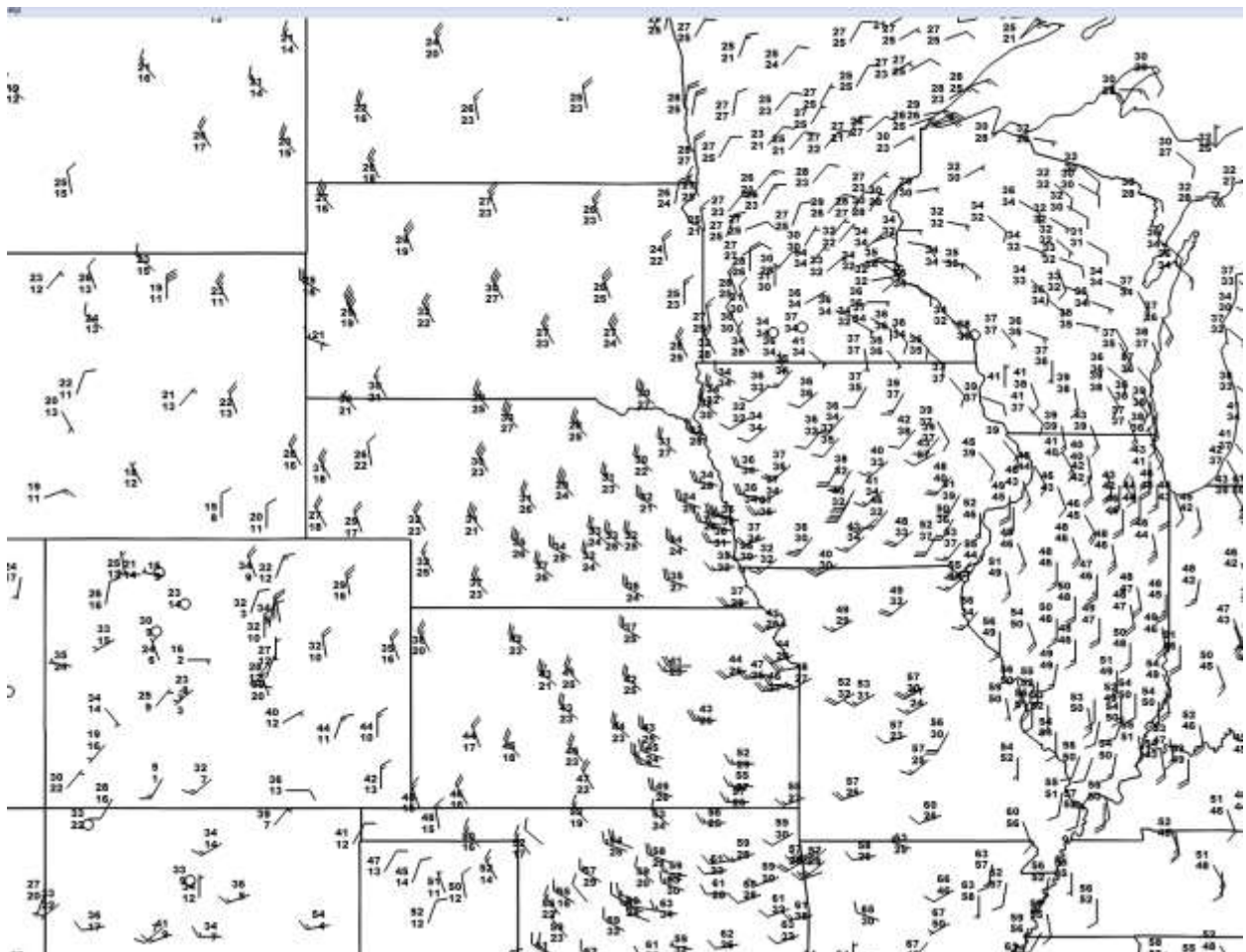
Wind Direction:

2) Oklahoma City, OK (central Oklahoma):

Temperature:

Dewpoint:

Wind Direction:



## Example 1: A very high example of work on this question

b) Fill in the blanks with appropriate responses. For example locations, any place or region is fine.

Köppen Classification	Brief Description of these Climates	Example Location with this Type
A	<u>Tropical</u>	<u>Brazil</u>
B	<u>Subtropical</u>	<u>Florida</u>
D	<u>Continental - cold</u>	<u>Oregon</u>
E	<u>Continental - cold</u>	<u>New York</u>

c) It's late June.

- 1) At what latitude is the Sun directly overhead? 23.5° N
- 2) How many hours of daylight should Lincoln receive? 15 hr
- 3) At about what latitude should the ITCZ be located? 0°
- 4) Roughly how many degrees is the sun above the horizon in Lincoln at noon? 73.5  
90 - (40 - 23.5)

d) Should Tennessee or Indiana have the greatest annual temperature range? Why?

2 Indiana, it's further north

e) Briefly describe how cloudcover affects the daily range of temperature.

2 During the day it can prevent the sun from heating the surface more and it will be cooler, @ night it can prevent heat from escaping making it warmer

### 8) Air Masses, Frontal Boundaries, and Midlatitude Cyclones (required)

On 10 February 2013, a powerful midlatitude cyclone traveled across North America. You will analyze some data from this case.

a) Using the surface map (on the data sheet at the end of the exam), which contains temperature, dewpoint, and wind information at many stations across the central United States, complete the following analysis:

- 1) Label the low pressure center with an 'L'.
- 2) Draw the cold front, warm front, and dryline with proper symbols.
- 3) Label the 4 air masses which occur around the low (e.g. mT).
- 4) What type of cyclone is this? Colorado Low

5) Does freezing rain seem likely north of the warm front of this cyclone? Briefly justify your response.

x Yes, dewpoints are below freezing

6) Does a blizzard look likely with this cyclone? If so, where would it be located?

2 Yes, E. South Dakota & Minnesota

7) The temperature in Scottsbluff, Nebraska (far western NE) is currently 31°F. What is a reasonable temperature for this air by the time it reaches northern Oklahoma?

37°F

8) Assess the potential for mountain snow along the foothills of the Rocky Mountains, from eastern Wyoming south to eastern New Mexico.

Not likely, dewpoints are very low



Type

2

9) Assess the potential for lake-effect snow around Lake Michigan. Briefly justify your assessment.

*Once temperatures cool over night there could be a possibility, but they'd have to drop significantly, you'd see LES on the west edge side the lake*

b) How do you expect the temperature, dewpoint, and wind direction to change at the following locations in the next 6–12 hours (think about frontal passages)?

1) Galena, IL (the far northwest corner of Illinois):

Temperature: *Decrease*

Dewpoint: *Decrease*

Wind Direction: *Shift to a North, NW Wind*

2) Oklahoma City, OK (central Oklahoma):

Temperature: *Decrease*

Dewpoint: *Decrease*

Wind Direction: *Become Northerly*

6

c) Using the visible satellite image (on the data sheet at the end of the exam), corresponding to the same time as the surface map you've analyzed above, complete the following analysis:

- 1) Mark the cyclone's dry slot with the letter 'D'.
- 2) Mark the cyclone's trough with the letter 'T'.
- 3) Draw a reasonable track of this cyclone from formation to dissipation.

3

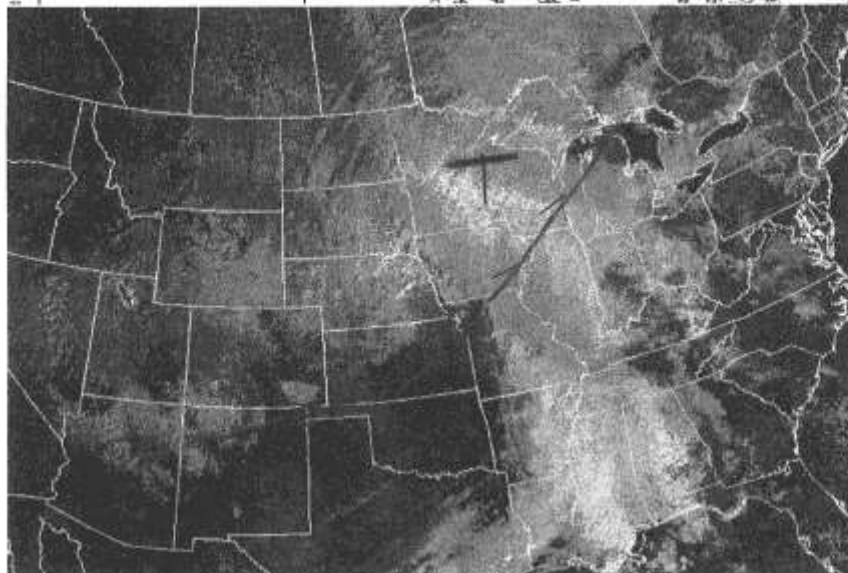
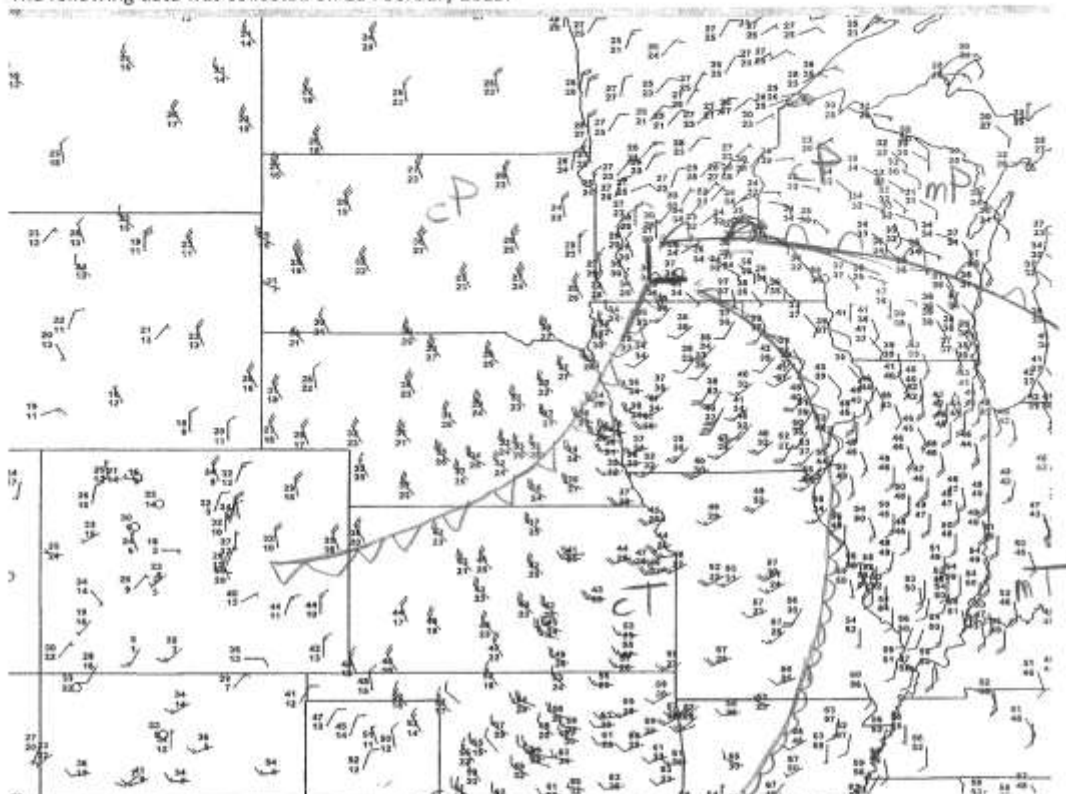
d) Answer the following questions about the cyclone lifecycle, using the 300-mb map provided here (from the same February 2013 event, but 12 hours prior to the surface data you've seen):



*Sub. G. Wind*

# Final Exam Data Sheet

The following data was collected on 10 February 2013:



## Example 2: An example of low-pass work on this question

b) Fill in the blanks with appropriate responses. For example locations, any place or region is fine.

Köppen Classification	Brief Description of these Climates	Example Location with this Type
A	Tropical and moist	Rainforest
B	Arid	Desert
D	Midlatitude severe winter	Lincoln NE
E	Polar	Alaska

c) It's late June.

- 1) At what latitude is the Sun directly overhead? 23.5°
- 2) How many hours of daylight should Lincoln receive? 15hrs
- 3) At about what latitude should the ITCZ be located? 27°
- 4) Roughly how many degrees is the sun above the horizon in Lincoln at noon? 27°

d) Should Tennessee or Indiana have the greatest annual temperature range? Why?

1.5 Indiana because there are no oceanic influences

e) Briefly describe how cloudcover affects the daily range of temperature.

2 clouds trap radiation and prevent insolation from reaching the surface

8) Air Masses, Frontal Boundaries, and Midlatitude Cyclones (required)

On 10 February 2013, a powerful midlatitude cyclone traveled across North America. You will analyze some data from this case.

a) Using the surface map (on the data sheet at the end of the exam), which contains temperature, dewpoint, and wind information at many stations across the central United States, complete the following analysis:

- 1) Label the low pressure center with an 'L'.
- 2) Draw the cold front, warm front, and dryline with proper symbols.
- 3) Label the 4 air masses which occur around the low (e.g. mT).
- 4) What type of cyclone is this? coastal cyclone
- 5) Does freezing rain seem likely north of the warm front of this cyclone? Briefly justify your response.  
x Yes Temps are cold enough and there is a lot of moisture in the atmosphere
- 6) Does a blizzard look likely with this cyclone? If so, where would it be located?  
x I don't think a blizzard is likely
- 7) The temperature in Scottsbluff, Nebraska (far western NE) is currently 31°F. What is a reasonable temperature for this air by the time it reaches northern Oklahoma?  
x

8) Assess the potential for mountain snow along the foothills of the Rocky Mountains, from eastern Wyoming south to eastern New Mexico.

2 There is cold air but not very much moisture. I would say that there is little chance of mountain snow

9) Assess the potential for lake-effect snow around Lake Michigan. Briefly justify your assessment.

High moisture, very likely

b) How do you expect the temperature, dewpoint, and wind direction to change at the following locations in the next 6 – 12 hours (think about frontal passages)?

1) Galena, IL (the far northwest corner of Illinois):

Temperature: 40

Dewpoint: 23

Wind Direction: westerly

2) Oklahoma City, OK (central Oklahoma):

Temperature: 64

Dewpoint: 45

Wind Direction: southerly

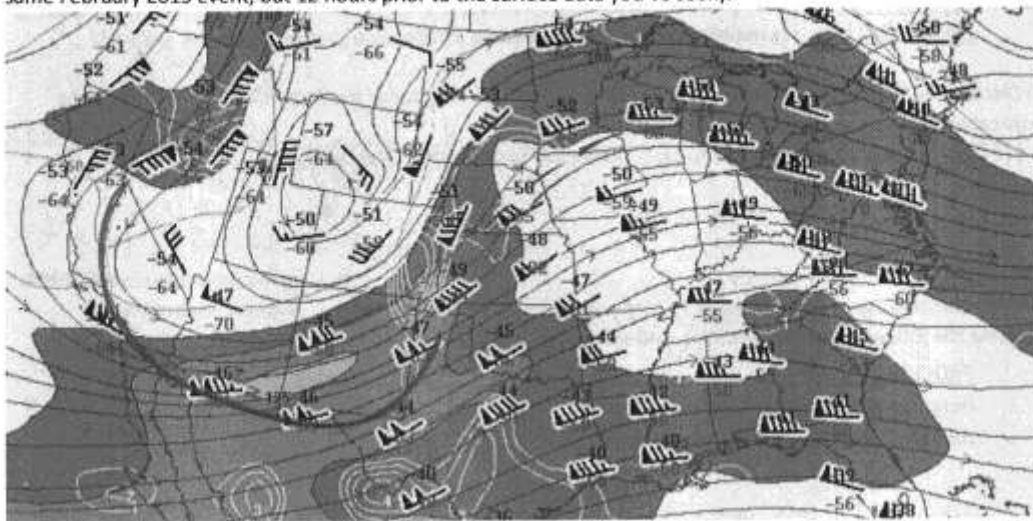
c) Using the visible satellite image (on the data sheet at the end of the exam), corresponding to the same time as the surface map you've analyzed above, complete the following analysis:

1) Mark the cyclone's dry slot with the letter 'D'.

2) Mark the cyclone's trough with the letter 'T'.

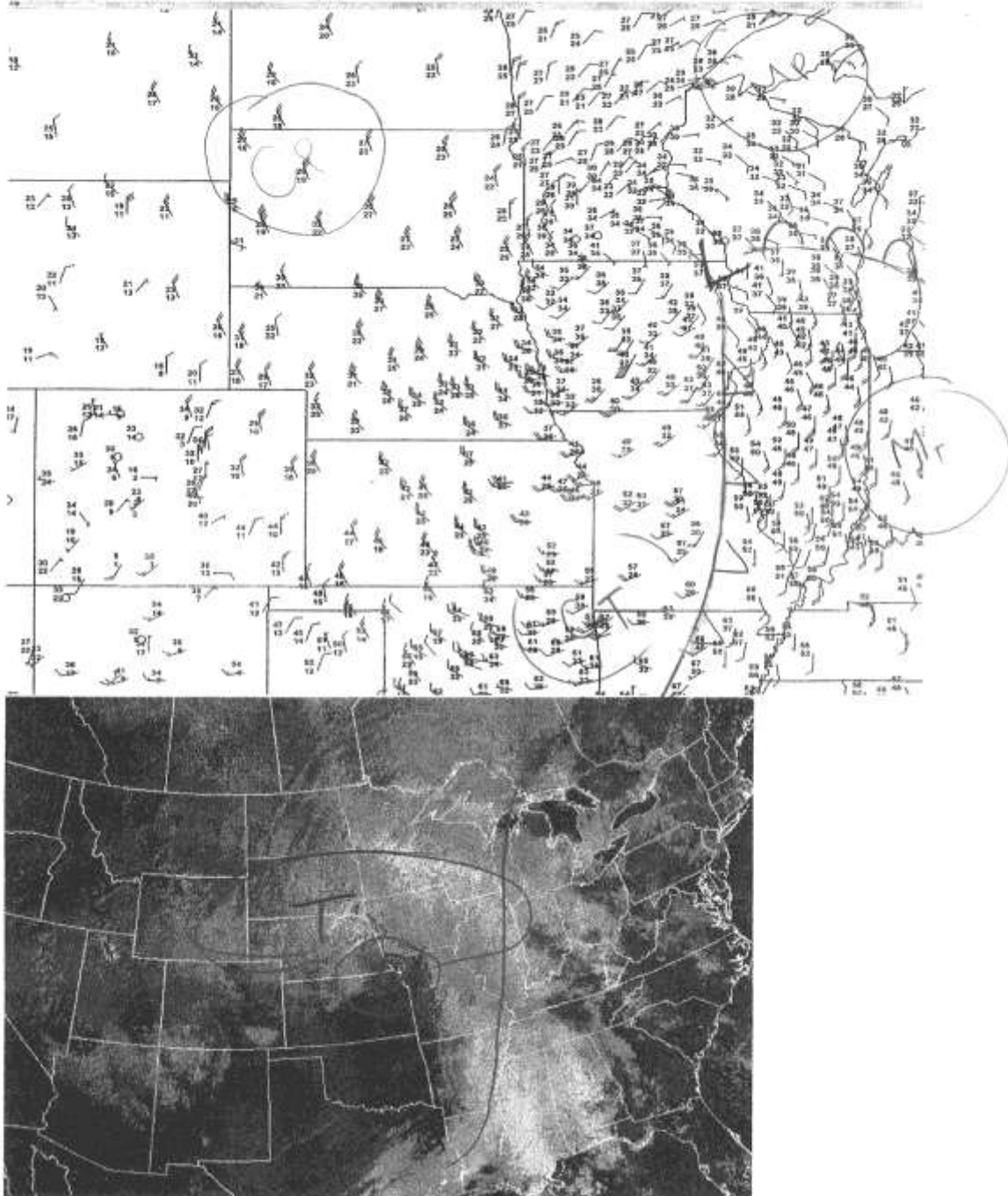
3) Draw a reasonable track of this cyclone from formation to dissipation.

d) Answer the following questions about the cyclone lifecycle, using the 300-mb map provided here (from the same February 2013 event, but 12 hours prior to the surface data you've seen):



Final Exam Data Sheet

The following data was collected on 10 February 2013:



# Appendix F: Homework Assignment 5

## Homework 5: Weather Feature Collection METR 200-150, Spring 2013

For this homework assignment, find examples of the following features in weather data from the Spring 2013 semester. You may use any type of data which shows the feature. You may also include data showing multiple features—as many features as you want in a single image are fine. Include your data with your homework submission, which can be paper or digital.

For each item:

- 1) Indicate on your data where the feature is located.
- 2) Write one sentence about how the feature affected nearby weather at the surface.

**Due Date:** This assignment is due on Tuesday 30 April (at the final exam), but you may turn it in anytime earlier. Turn it in by Tuesday 16 April for an extra 5%.

- A) Upper-level ridge (700 mb or above)
- B) Upper-level trough (700 mb or above)
- C) Strong surface temperature gradient
- D) Inversion in a sounding
- E) Polar or subtropical jetstream
- F) Surface cold front
- G) Surface warm front
- H) Surface dryline
- I) Colorado Low
- J) Freezing rain sounding
- K) Snow visible from space
- L) Squall line or MCS in radar imagery
- M) Supercell in radar imagery
- N) Tornado-conducive sounding or hodograph
- O) Tropical wave or cyclone in satellite or surface observations

# Appendix G: Homework Assignment 6, with Examples of Student Work

## Homework 6: Journal Article or News Article Review METR 200-150, Spring 2013

For this assignment, you have two options:

- 1) Choose a journal article about a weather-related topic (some suggestions are given below). Read the article, and turn in 2 – 3 well-written pages (1.5-spaced, 1" margins) which include the following elements:
  - Summary of the journal article (1 – 2 pages)
  - Critique of the article's writing and content—is the article well- or poorly-written? What do you like or not like about the writing style, clarity of presentation, organization, figures, etc.? This element is open-ended; I'm not looking for anything specific.
  - A few key things you learned from the article, and how they relate to course material
- 2) Find a news article which focuses on some aspect of weather and/or climate. Your article may be from a print or online source. Read the article, and turn in 2 – 3 well-written pages (1.5-spaced, 1" margins) which include the following elements:
  - Detailed analysis of the article's scientifically-valid points
  - Detailed analysis of what points in the article are not scientifically sound, and why they are not sound
  - Critique of the article's writing and content—is the article well- or poorly-written? What do you like or not like about the writing style, clarity of presentation, organization, etc.? This element is open-ended; I'm not looking for anything specific.

Your grade on this assignment (either option) will be determined 60% by your quality of discussion of the items above, and 40% by your quality of writing and presentation of your ideas. Points may also be deducted for not following length or formatting guidelines.

**Due Date:** This assignment is due on **Tuesday 30 April** (at the final exam), though you may turn it in anytime during the semester. Turn it in by Thursday 18 April for an extra 5%.

Below is a list of possible journal articles. *If you'd like to review an article on a different topic, let me know and we can find a suitable article for you to review.* The site at which you can find the following articles is <http://journals.ametsoc.org/search/advanced> Enter the lead authors' last name and year of publication and it should be easy to find your article.

## Example 1: A very high example of work on this assignment

$$\begin{array}{r} D \quad 58 \\ W \quad 39 \\ \hline 97.0 \% \end{array}$$

Tornado detection has always been a difficult task for meteorologists. Many tornados can't be spotted by the human eye which leaves weather instruments to help detect tornados. Standard Doppler radar has helped in this manner but by itself it doesn't always produce accurate results. Dual-polarization radar has become an effective tool for detecting tornados seen in the article, "Polarimetric Tornado Detection." The article discussed how tornado detection can be characterized by the cross-correlation coefficient and the differential reflectivity.

Dual-polarization is capable of classifying different hydrometeor types and the differences between meteorological and nonmeteorological scatterers. The cross-correlation coefficient and the differential reflectivity are two factors that can help detect tornados. Tornadic debris is very different from all other hydrometeors. Tornadic debris is a random collection of things that all have irregular shapes and a refractive index that differs greatly from other hydrometeors. The differential reflectivity for randomly oriented scatterers is equal to or very close to zero. The cross-correlation coefficient is also very different from many hydrometeors. Tornadic debris has larger particles, more irregular shapes, a higher refractive index, and a less organization than typical liquid or frozen hydrometeors.

Differential reflective varies depending on the particles in the air. For tornadic debris, the values are extremely close to zero while large rain drops would be around 3-5 for differential reflectivity. The cross-correlation coefficient is usually between 0.980 and 0.997 for rain or snow. Hail has slightly lower coefficient values but the lowest any coefficient value that hail caused was 0.75 which was 13 cm hail. Hail usually doesn't cause the coefficient value to drop below 0.85.

The article covered 3 tornadic events around the Oklahoma City, OK area. The first was on May 3, 1999 and the other two were May 8 and 9, 2003. For the first event, the reflective differential value was almost zero and the cross-correlation coefficient was less than 0.4. The Cimarron radar was hit by the storm so it missed part of the data but the values recorded show a tornado existed during this event. During the May 8<sup>th</sup> event, a value of 0.2 was recorded for the cross-correlation coefficient which was unprecedented low. The May 9<sup>th</sup> event yielded similar data with differential reflective values near zero and low cross-correlation coefficient values.



During each of the three events, a tornado was present which suggests a relationship between a tornado and the values for differential reflectivity and the cross-correlation coefficient. For each event, the radar scans were analyzed and “differential reflectivity debris signatures” and “cross-correlation coefficient signatures” were counted and used to calculate the minima and mean values for differential reflectivity and cross-correlation coefficient. Despite some of the gaps in radar data, the progression of radar data in each event matches the ground results. The minima for differential reflectivity and cross-correlation coefficient match the tornado peak intensity. While it seems these events are related that is a couple small issues. The radar can’t detect the tornado until a sufficient debris cloud forms. Also, the debris manages to stay in the air for about 6-10 minutes after the tornado ended which can cause a false positive with the results.

Further analysis shows that not all tornados showed this signature. Some smaller tornados didn’t cause enough destruction to loft enough debris. Also, some of the tornados were short lived so the radar sweep of 6 minutes wasn’t able to capture the short lived tornado. However, for all nontornadic supercell events, this signature didn’t exist. The following is the criteria for a polarimetric tornado detection: 1) a hook echo, 2) cross-correlation coefficient  $< 0.8$ , 3) a pronounced vortex signature on the Doppler velocity field, 4) differential reflectivity  $< 0.5$ , and 5) radar reflectivity  $> 45$  dBZ. Besides the hook echo, the best criterion is cross-correlation coefficient. The cross-correlation coefficient isn’t affected by radar miscalibration, partial radar blockage beam, and attenuation in precipitation like differential reflectivity.

Nearly all of Doppler radar detection of tornados in the past used the kinematic properties of storms. This article shows that dual-polarization radar can also detect tornados and serves as a good complement to the traditional detection system. The dual-polarization detection may help detect tornados that the traditional system didn’t catch. Also, it could offer a pinpoint location of tornados which will help when issuing warnings for specific areas that could be impacted by the tornado.

Overall, this article was well written. It is 10 years old so it doesn’t present any new information now but at the time it was new information. The article is well organized in that it gave all needed background information, new data, analysis of the data, and a conclusion. The article is written such a way that it doesn’t require an excessive amount of background information to understand the concepts. All of the figures included were relevant and provided an excellent view of the data.

Tornado detection has been a tough issue for meteorologists. Not all tornados can be spotted by the human eye which means instruments and technology need to help fill in that gap. This article is very interesting and provides a lot of useful information. I knew tornado detection was difficult and that there were certain ways radar could help identify tornados but didn't know much about those methods. From this article, I learned about how differential reflectivity values and cross-correlation coefficients help identify tornados. Traditional radar methods of identifying tornados can catch some but using polarimetric tornado detection can improve the detection rate. However, polarimetric tornado detection isn't perfect so it serves as a good complement to other methods.

This article is directly related to course material. We discussed supercells and tornados in class. Polarimetric tornado detection can help separate nontornadic supercells from tornadic supercells. We discussed tornado detection during class which is what is discussed during in this article. We also discussed how to read radar maps during class and in a lab. This article is about reading certain radar maps while focusing on specific values to identify tornados. This article helps improve tornado detection and which improves the forecasts and warnings that meteorologists can offer.

Ryzhkov, A. V., T. J. Schuur, D. W. Burgess, P. L. Heinzelman, S. E. Giangrande, and D. S. Zmich, 2005: Polarimetric tornado detection. *J. Appl. Meteor.*, **44**, 557 – 570.

## Example 2: A very high example of work on this assignment

$$\begin{array}{r} D \ 59 \\ W \ 39 \\ \hline 98.0 \end{array}$$

| 1  
|

In the article, The July 1995 Heat Wave in the Midwest: A Climatic Perspective and Critical Weather Factors, Kenneth Kunkel, Stanley Changnon, Beth Reinke and Raymond Arritt discussed an intense heat wave that caused hundreds of fatalities in mid-July 1995. During this heat wave, fatalities were reported in 19 states, with 87% of the fatalities occurring in the Midwest. The paper describes the 1995 heat wave, explores the weather conditions that caused the heat wave, and contrasts it with past heat waves of similar duration to assist the reader in gaining an understanding of the phenomena.

Analysis of the data showed that an upper-level ridge developed over the southwestern United States on July 7, 1995, which resulted in rising temperatures in the Great Plains. During the initial phase of the heat wave, maximum temperatures exceeded 35°C (95°F); by July 10, maximum temperatures exceeded 40°C (104°F) in parts of Kansas; and at the end of the heat wave, temperatures exceeded 42°C (107.6°F) in the Great Plains and Central Wisconsin. The upper-level ridge initially developed over the southern Rocky Mountains and spread across the Great Plains, across the northern Midwest and along the northeastern United States coastline.

The authors pointed out that heat waves in the central and eastern United States are frequently accompanied by relatively high near-surface atmospheric water vapor content. However, this particular heat wave was accompanied by unusually high water vapor content, with many locations reporting daily average dewpoint temperatures in excess of 25°C (77.0°F). This resulted in very high apparent temperatures.

When examining the historical perspective of the July 1995 heat wave as compared to past heat wave data, the authors discovered that the 1995 heat wave did not compare in length with other past multi-week heat waves. It was also ascertained that the summer of 1995 was not the hottest summer in recent history as mid-August 1988 reported a longer heat wave with greater intensity than mid-July 1995.

Critical weather factors that were involved with the mid-July 1995 heat wave included high dewpoint temperatures and urban heat island phenomenon. It was surprising during this particular heat wave to view the appearance of very high dewpoint levels in the upper Midwest. Dewpoint value levels to the southwest and south of this region were generally in the range of 20° - 23°C (68.00°F - 73.40°F) in the days prior to this heat wave. Therefore, the authors concluded that advection could not be used as an explanation for the high dewpoint values. The proposed explanation for the high moisture values were caused by the effect of local evaporation.

The authors reached this hypothesis because local evaporation on surface values of dewpoint levels is dependent on several factors including soil moisture availability, meteorological potential for evaporation, and the depth of boundary level vertical mixing.

Kunkel's operational soil moisture model was used to estimate the soil moisture in the Midwest on July 12, 1995. The analysis showed that soil moisture was near or above average during this time period as the result of a very wet spring and early summer. This indicated that there was abundant soil moisture available for evapotranspiration.

The vertical mixing depth was estimated using radiosonde data taken at 0000 UTC, which was indicative of the time of maximum mixing depth during the heat wave from a north-south cross section of station throughout the heat wave area. Stations used for analysis included International Falls, MN, Green Bay, WI, Davenport, IA, Lincoln, NE, Topeka, KS, and Little Rock, AK. Prior to the heat wave, maximum mixing depths at Davenport, IA were approximately 1100 m, but as the heat wave developed, the maximum mixing depths decreased to a minimum of approximately 500 m. Mixing depths were analyzed for all six locations and showed that during the most intense heat wave, the mixing depths were considerably less than 1 km in the upper Midwest.

Physiological Equivalent Temperatures (PET values) were observed during the time period of July 10 -15, 1995. The authors proposed that actual evaporation was not much less than the potential evaporation because of abundant soil moisture. However, combining evaporation with very shallow mixing depths, causes significant increases in PET values. Therefore, the local evaporation played a significant role in creating high dewpoint temperatures, which in turn created exceptionally high apparent temperatures.

A well documented phenomenon called urban heat island is an important consideration in large cities during a heat wave. An analysis of the average daily maximum and average daily minimum temperatures during the heat wave time period were evaluated. In addition, average moisture conditions in Chicago were evaluated. The data showed that the urban-rural difference observed in the 1995 heat wave was pronounced when compared to the average heat island conditions during other summers.

Although the mid-July 1995 heat wave was short-lived it was the most intense heat wave of the latter half of the twentieth century for the northern Midwest. Only the heat waves of 1911, 1916, 1934 and 1936 were ranked comparably or of greater intensity in Chicago. It was

concluded that the extremely high apparent temperatures were one result of high dewpoint values. In addition, the urban heat island was pronounced during this heat wave. These findings suggest that forecasters of heat waves need to carefully consider the abnormal heat island conditions that will exist, as well as local physical influences on the heat island.

I found this article to be well-written. The authors gave a succinct statement of what they were planning to research. They clearly described their objectives, research questions, and hypothesis. It gave a detailed analysis of the scientifically-valid points. I thought that the tables and figures included in the article helped me to understand the points that the authors were making. The tables and figures were presented in a manner that allowed the reader to understand the data without relying on the written text. The paper was well organized and used headings to help the reader understand more clearly what each aspect of the paper was going to address.

After reading this article, I was able to finally understand how the area of an Upper Level ridge effects warm temperatures. I also found it interesting that this heat wave was also drier than the typical heat waves that the Midwestern United States normally get. By reading this article, I was able to finally understand how upper level ridges can have an effect upon the temperatures at the surface.

## Example 3: A low example of work on this assignment

Discussion: 46.5

Writing: 29

Total = **75.5%**

Although Mesocyclone convection systems vary, one is severely understudied. This MCS occurs along strong cold fronts during the cool season. It may produce little to no cloud-to-ground lightning. More importantly, it consists of strong, damaging winds.

These strongly forced, low-instability convection lines described above present several issues. First off, little is published about these convection lines. This leads to forecasters have a dilemma on issuing warnings for these convection lines. Severe thunderstorms warnings, watches, or high wind warnings may not fit the criteria for these lines. This is due to the absent of cloud-to-ground lightning and wind damage occurring in the mesocyclone (Van Den Broeke et al., 2005). Another issue on hand is that National Weather Service does not have a way to identify severe winds reports that are convective and nonthundering. This leads to differences in practice and in storm reports. The final issue is difficulty categorizing damage reports. There is differences in whether the damage occurred when the winds were convective or nonconvective.

There were two examples mentioned in the article. One was November 1998 and the other was March 2002. Both convection lines started out as a trough. These troughs would develop and become negatively tilted. Cells would form together, which would deepen the cyclone. As a result, a large convection line was formed.

After the convection line was produced, cloud-to-ground lightning was reported in both cases. At first CG lightning would be frequent, but would decrease as the convection line progressed. CG lightning has many factors to its development. There must be enough CAPE to

support vertical motion. Lightning is also favorable if there is instability in the lower mixed phase region (Van Den Broeke et al., 2005).

Along with these convection line examples, weather conditions varied. In the nonconvective regions, there was either nonconvective high wind or blizzards reports. In the convective regions, severe winds, hail, and sometimes tornadoes were reported. By far, the most dangerous condition in a strongly forced, low-instability convection lines are severe winds that can last well into the dissipating phase.

This article was well-written. It was interesting that the authors presented useful information about a topic that is very understudied. It was surprising that the National Weather Service does not have a way to identify severe wind as convective and nonthundering. This brings confusion to forecasters on producing storm reports. I also liked the applied examples in the article. I found it very useful that the figures were broken down by time. That way, you can see how the convection line progressed and strengthened in exact locations. You could also see what weather conditions were caused by the convection lines (high winds, blizzard, hail, tornadoes, etc) and where. This was done through the use of upper-level surface maps, radar, and soundings.

What I learned is, that convection lines vary drastically. In this case, derecho and severe thunderstorm-like conditions may be present without the cloud-to-ground lightning present. This shows that convection lines can strengthen with or without certain conditions. I also learned that issuing watches or warnings may be difficult to establish for these convection lines. They somewhat share the same qualities as a severe thunderstorm warnings, watches, and high wind warnings. I also learned that the strongly forced, low-instability convection lines generally form in the same way. They start off with a trough and then become negatively tilted. They also have

the same general location of the weather repercussions with convection and nonconvection (high winds and blizzards).

#### Works Cited

Van Den Broeke, M., D. Schultz, R. Johns, J. Evans, and J. Hales, 2005: Cloud-to-ground lightning production in strongly forced, low-instability convective lines associated with damaging wind. *Wea. Forecasting*, 20, 517-530.